Thesis/
Reports
Dark,
S. J.

A LANDSCAPE-SCALE ANALYSIS OF MAMMALIAN CARNIVORE DISTRIBUTION AND HABITAT USE BY FISHER

A LANDSCAPE-SCALE ANALYSIS OF MAMMALIAN CARNIVORE DISTRIBUTION AND HABITAT USE BY FISHER

by

Shawna J. Dark

A Thesis

Presented to

The Faculty of Humboldt State University

In Partial Fulfillment

of the Requirements for the Degree

Masters of Science

May 1997

National FS Library
USDA Forest Service

AUG 17 2011

240 W Prospect Rd
Fort Collins CO 80526

A LANDSCAPE-SCALE ANALYSIS OF MAMMALIAN CARNIVORE DISTRIBUTION AND HABITAT USE BY FISHER

by

Shawna J. Dark

Approved by:

Richard T. Golightly, Chair — 12 May 1997 — Date

T. Luke George, Committee Member — 14 May 1997 — Date

David W. Kitchen, Committee Member — 12 May 1997 — Date

Director, Natural Resources Graduate Program — 19.V.97 — Date

97/WM-351/05/08

Natural Resources Graduate Program Number

Approved by the Dean of Graduate Studies

John P. Turner, Jr. — 17 Aug 97 — Date

ABSTRACT

Forest carnivore distribution was assessed and landscape characteristics that best discriminated habitat used by fisher (Martes pennanti) for resting and other activities was determined on the Shasta-Trinity National Forest in 1994-1995. The distribution of forest carnivores at the scale of the landscape was assessed using track-plates. Log-linear analysis revealed a significant negative interaction between gray fox (Urocyon cinereoargenteus) and black bear (Ursus americanus) ($\chi^2 = 12.40$, df = 1, $P < 0.001$). The amount of area with 51-75% canopy closure successfully discriminated locations where black bear were detected using stepwise logistic regression ($\chi^2 = 14.34$, $P < 0.01$; 69% correct classification). Gray fox were detected at 72% of the sample locations and no landscape variables were significantly different between locations where gray fox were and were not detected. The total amount of core area successfully discriminated landscapes where ringtail were detected ($\chi^2 = 7.62$, $P < 0.01$; 79% correct classification).

Fisher were detected in areas where more habitat classified as Douglas-fir (km^2) with 50-75% canopy closure (km^2), less barren area, greater density of low use roads (m), and fewer disjunct core areas. Landscape habitat characteristics at fisher rest sites (n = 74) and at stations (n = 79) within fisher home ranges were quantified within a 28.3 ha circular buffer. Fisher rest site buffers had a greater amount of 50-75% canopy cover, fewer disjunct core areas, and a greater amount of Douglas-fir than stations where fisher were not detected ($F = 7.68$, df = 1,122, $P = 0.001$). There was no significant difference

in landscape habitat characteristics between fisher rest sites and sites where fisher were detected at track-plates ($F = 1.57$, $df = 9,89$, $P = 0.14$).

Use of fisher as a Management Indicator Species for carnivores may be inappropriate because their distribution was not representative of other carnivores at the study area. Also, the distribution of generalist species (gray fox and black bear) was influenced more by interspecific interactions than the landscape characteristics measured. Finally, fisher rested in and were detected in landscapes with specific configurations. My results suggested that fisher on the Shasta Trinity National Forest used Douglas-fir stands that were structurally complex with dense canopy closure, characteristics typically found in riparian sites at the study area. Fisher on the Shasta-Trinity National Forest also appeared to use landscapes with more contiguous, unfragmented Douglas-fir forest and less human activity.

ACKNOWLEDGMENTS

The U.S. Bureau of Reclamation and the U.S. Forest Service provided funding for this study under the Trinity River Basin Project. Several biologists associated with these institutions supported this project, including M. Gertsch, C. Roberts, and W. Brock. The California Department of Fish and Game and the California Department of Forestry and Fire Protection also provided support and funding. In particular, I would like to thank E. Burkett for the use of a vehicle and an employee during field data collection.

I thank my committee members Dr. George and Dr. Kitchen. Their time and patience was very helpful in the development of this thesis. I particularly thank my advisor, Dr. Golightly for his support.

Several field technicians and volunteers made the data collection for this thesis possible. I thank D. VanBaren, J. Philips, and J. Storley. In particular, I would like to thank J. Woods for volunteering his entire summer to this project, without his loyal effort the completion of surveys would have been difficult at best. I thank E. Craig for assisting with data entry and the digitizing of roads at the study area.

I dedicate this thesis to my family, including my husband, all of whom provided financial and moral support. In particular I thank my parents who provided encouragement and taught me respect for nature early in life. Finally, I thank my husband and field assistant, Christopher Lanning. His constant support and true dedication to me and all aspects of this study cannot be rewarded enough.

TABLE OF CONTENTS

	Page
LIST OF TABLES	viii
LIST OF FIGURES	x
INTRODUCTION	1
STUDY AREA	6
METHODS	9
Forest Carnivore Distribution	9
Track-plate Surveys	9
Landscape-Level Habitat Characteristics at Track-plate Locations	13
Landscape-Level Habitat Use at Fisher Rest Sites	17
Radio-Telemetry	18
Home Range Calculation	19
Landscape-Level Habitat Characteristics at Rest Sites and Track-plate Locations	19
Data Analysis for Forest Carnivore Distribution	20
Species Interactions	20
Landscape-Level Habitat Analysis	21
Data Analysis for Landscape-Level Habitat Use at Fisher Rest Sites	23
Assumptions and Limitations	23

TABLE OF CONTENTS (CONTINUED) Page

RESULTS 27

Forest Carnivore Distribution 27

Species Interactions 27

Landscape-Level Habitat Analysis 29

Black Bear 29

Gray Fox 29

Ringtail 34

Fisher 34

Landscape-Level Habitat Use at Fisher Rest Sites 40

DISCUSSION

Forest Carnivore Distribution 44

Species Interactions 44

Landscape-Level Habitat 45

Black Bear 45

Gray Fox 46

Ringtail 47

Landscape-Level Habitat Use By Fisher 48

Management Recommendations 52

REFERENCES CITED 54

APPENDICES 60

LIST OF TABLES

Tables		Page
1	Variables measured including habitat and canopy cover categories identified in a raster based GIS for the Shasta-Trinity Fisher Project study area in Shasta and Trinity Counties, May 1994 - August 1995.	15
2	Detection ratios calculated for carnivores during three surveys on the Shasta-Trinity National Forest, on Shasta and Trinity Counties.	28
3	Eleven landscape variables used in stepwise procedure for each carnivore detected on the Shasta-Trinity National Forest from May 1994 to August 1995	30
4	Univariate comparisons of 11 landscape characteristics where black bear were detected versus where they were not detected from May 1994 to August 1995	32
5	Results from Stepwise Logistic Regression with variables that best discriminated between landscapes where black bear were detected and landscapes where they were not detected on the Shasta-Trinity National Forest from May 1994 to August 1995	33
6	Univariate comparisons of 11 landscape characteristics where gray fox were detected versus where they were not detected from May 1994 to August 1995	35
7	Results from Stepwise Logistic Regression with variables that best discriminated between landscapes where gray fox were detected and landscapes where they were not detected on the Shasta-Trinity National Forest from May 1994 to August 1995	36
8	Univariate comparisons of 11 landscape characteristics where ringtail were detected versus where they were not detected from May 1994 to August 1995	37

LIST OF TABLES (CONTINUED)

Tables		Page
9	Univariate comparisons of 11 landscape characteristics where fisher were detected versus where they were not detected from May 1994 to August 1995	38
10	Results from Stepwise Logistic Regression with variables that best discriminated between landscapes where fisher were detected and landscapes where they were not detected on the Shasta-Trinity National Forest from May 1994 to August 1995	39
11	Nine landscape variables used to compare fisher rest site locations to stations where fisher were and were not detected on the Shasta - Trinity National Forest from May 1994 to August 1995	41
12	Results from t-tests comparing landscape characteristics within Fisher rest site buffers and station buffers where Fisher were not detected from May Through August 1994 and 1995 on the Shasta-Trinity National Forest in Shasta and Trinity Counties, California	43

LIST OF FIGURES

Figure		Page
1	Approximate location of Shasta-Trinity Fisher Project study area in Shasta and Trinity Counties, California. Study area does not include the shaded regions (Trinity Alps Wilderness Area and the Southeast corner of figure)	7
2	Portion of study area illustrating station (a single track-plate) and segment (a series of three stations) arrangement on the landscape. All stations were separated by 1 km. Each segment consisted of three stations. Segments were separated by 3 km. A total of 42 segments were placed throughout the landscape	10
3	Illustration of station and segment arrangement on the Shasta-Trinity National Forest used for examination of the distribution of mammalian forest carnivores and landscape habitat use by fisher. Each circle represents one station. A cluster of three circles represents one segment. Surveying was conducted from May 1994 to August 1995.	12
4	Figures 4A through 4D represent the distribution of four forest carnivores on the Shasta-Trinity National forest detected from May 1994 to August 1995. Filled shapes represent locations where each species was detected and open shapes represent locations where the species was not detected.	31

INTRODUCTION

Historically, many wildlife investigations have focused at a fine spatial scale (James and Shugart 1970, Larson and Bock 1986, Block and Brennan 1993). Fine scale studies (Callas 1987, Seglund 1995) have analyzed microsite measurements of habitat within a relatively small area (e.g.: <0.04 ha plots), but fine scale studies cannot be used to assess habitat use at the stand or landscape scale. Habitat at the landscape scale includes the examination of the physical distribution, relationship, and area of habitat types across a forest or series of stands (Weins 1989, Clark et.al. 1993, Franklin 1993).

Land use by humans such as timber harvesting, the development of roads, recreational areas, and housing has reduced and fragmented the forested lands available to wildlife populations throughout the Pacific Northwest (Raphael and Rosenburg 1986). In California, the decrease in late-seral forest habitat and an associated increase in forest fragmentation has had a negative impact on several wildlife populations, most notably the Northern Spotted Owl (Strix occidentalis caurina) (Gutiérrez et al. 1995). However, little is known about how these altered landscape patterns impact the distribution and habitat use of mammalian forest carnivores.

Maintaining the viability of wildlife species has become a primary consideration in forest management practices throughout the United States (Terbourgh 1974, Noss 1983, U. S. D. I. 1994). This concern is especially acute for wide ranging mammals who traverse very large areas of land and whose densities are relatively low. National forests

must enhance the habitat of selected management indicator species to improve forest health (Salwaser et al. 1983, U.S.D.I. 1994). Management indicator species are those species whose populations are used as an index to measure the effects of management practices on other species with similar habitat requirements and from a similar guild (Salwaser et al. 1983). These species are also selected because it is believed that their population changes are indicative of the effects of management activities.

The fisher (Martes pennanti) has been identified as a management indicator species in California in response to National Forest Management Act (section 219.19). This mid-sized terrestrial carnivore is found in the northwestern and northeastern regions of North America. In California, fisher are present in the northwestern Klamath Province and in the southern Sierra Nevada mountains (Ruggerio et al. 1994, Lewis and Zielinski 1996). In the region between these two populations, fisher are no longer present or occur at low densities (Ruggerio et al. 1994). Apparent decreases in their distribution as well as potential declines in their population, has prompted some biologists to argue that fisher may be on the verge of extirpation in regions of Washington (Aubry and Houston 1992). Since 1990, the U. S. Fish and Wildlife Service has been petitioned twice to identify the fisher as a threatened species in the Pacific northwest. Both petitions were unsuccessful due to the lack of information about fisher in California. The Environmental Impact Statement for the Northwest Forest Plan (U.S.D.I. 1994) emphasized that information about fisher in the Pacific Northwest was needed in order to establish appropriate management plans (U.S.D.I. 1994).

Several studies of habitat use by fisher have been conducted (Johnson 1984, Douglas and Strickland 1987, Arthur et al. 1989). In the northeastern United States Arthur et al. (1989) found that fisher used coniferous forests significantly more than deciduous forests. Fisher were also associated with large contiguous areas of late-successional forests and with complex forest structure (Johnson 1984, Douglas and Strickland 1987, Arthur et al. 1993). The forests in the West are different structurally and compositionally than the eastern United States. Therefore, insights obtained from eastern fisher are not comparable to fisher ecology in the West due to differences in habitat and topography between the two regions.

In California, Buck et al. (1994) found that fisher in the Klamath Province used large contiguous areas of late-successional forests and areas with continuous canopy closure. They avoided hardwood stands and open areas. Fisher movements recorded by Buck et al. (1994) suggested that major and minor drainage systems, as well as ridges, were important aspects of topography for movement by fisher. They also suggested that fisher rested in locations with different habitat features than where they foraged and traveled. Seglund (1995) also found that the distance to human disturbance, drainages, and large dbh Douglas-fir trees were important microsite features at fisher rest sites on the Shasta-Trinity National Forest.

The purpose of my investigation was to examine the distribution of fisher in relation to landscape-scale habitat features and to examine the distribution of other mammalian forest carnivores in that landscape. Distributional information on mammalian carnivores was assessed using track-plates. Scientists have only assessed habitat use of

fisher in relation to physical attributes with little or no consideration of the influence of other mammalian carnivores. In particular, previous studies with track-plates have not assessed potential correlations in species detection that may influence further habitat selection analyses. Therefore, I examined both biological and physical attributes in this study.

To identify potential species interactions between mammalian forest carnivores, I assessed correlations in the distribution of fisher and three other species, black bear (Ursus americanus), gray fox (Urocyon cineroargenteus), and ringtail (Bassariscus astutus). Assessing correlations in species distribution allowed for the identification of potential species interactions that may influence distribution. Next, to examine whether fisher may serve as a Management Indicator Species for other forest carnivores at the study area, I also assessed the habitat associations of each species. If fisher were distributed with respect to different landscape features than other mammalian carnivores, fisher may not be an appropriate Management Indicator species for them.

A second objective of this investigation was to examine fisher habitat use at a landscape scale. However, in order to demonstrate landscape level use of habitat, it was necessary to know where fisher were located (commonly available in radio telemetry studies), but also where they were absent (not usually available in telemetry studies). Furthermore, rest sites may not represent areas used for foraging and traveling or locations where fisher are not present. Patterns of presence and absence of detections obtained through the use of sooted track-plates can identify habitat used by fisher. When using the appropriate survey duration, track-plates can also identify areas that are either

not used by fisher or areas where fisher densities are low (Fowler and Golightly 1994). Therefore, I compared fisher rest sites to positive track-plate locations to determine if habitat features used for resting differed from track-plate sites where fisher were detected (and potentially used for foraging and travel). Further, to define areas used and unused by fisher at the study area, I compared sites where fisher were not detected to fisher rest sites.

STUDY AREA

The study was conducted on the Shasta-Trinity National Forest (STNF), Weaverville District, in Shasta and Trinity Counties. The study area was approximately 500 km^2 surrounding Clair Engle Lake in the Trinity River Basin (Figure 1). Elevations range from 610 m to 1500 m throughout the study area. Forests above 1370 m in elevation were not included in the study area due to poor accessability.

The study area was primarily conifer forests and northern woodland communities as described by Holland and Keil (1990). The dominant trees species were Douglas-fir (Pseudotsuga menziesii), incense cedar (Libocedrus decurrens), ponderosa pine (Pinus ponderosa) and black oak (Quercus kellogii). Woodland communities within the study area consisted primarily of black oak, canyon live oak (Quercus chrysolepis), big leaf maple (Acer macrophyllum), gray pine (Pinus sabiana), and oregon white oak (Quercus garryana).

During the study temperatures ranged from 17°C to 40°C during summer and from -6°C to 10°C during winter. Summers were typically warm and dry with occasional rain showers. During winter, snowfall varied from 6 cm at lower elevations to 90 cm at higher elevations.

The Trinity River Basin was characterized by widespread utilization of natural resources. Mining and intense timber harvesting have occurred throughout the area over the past 50-100 years (U.S.D.I. 1990). The basin was characterized by a patch work of

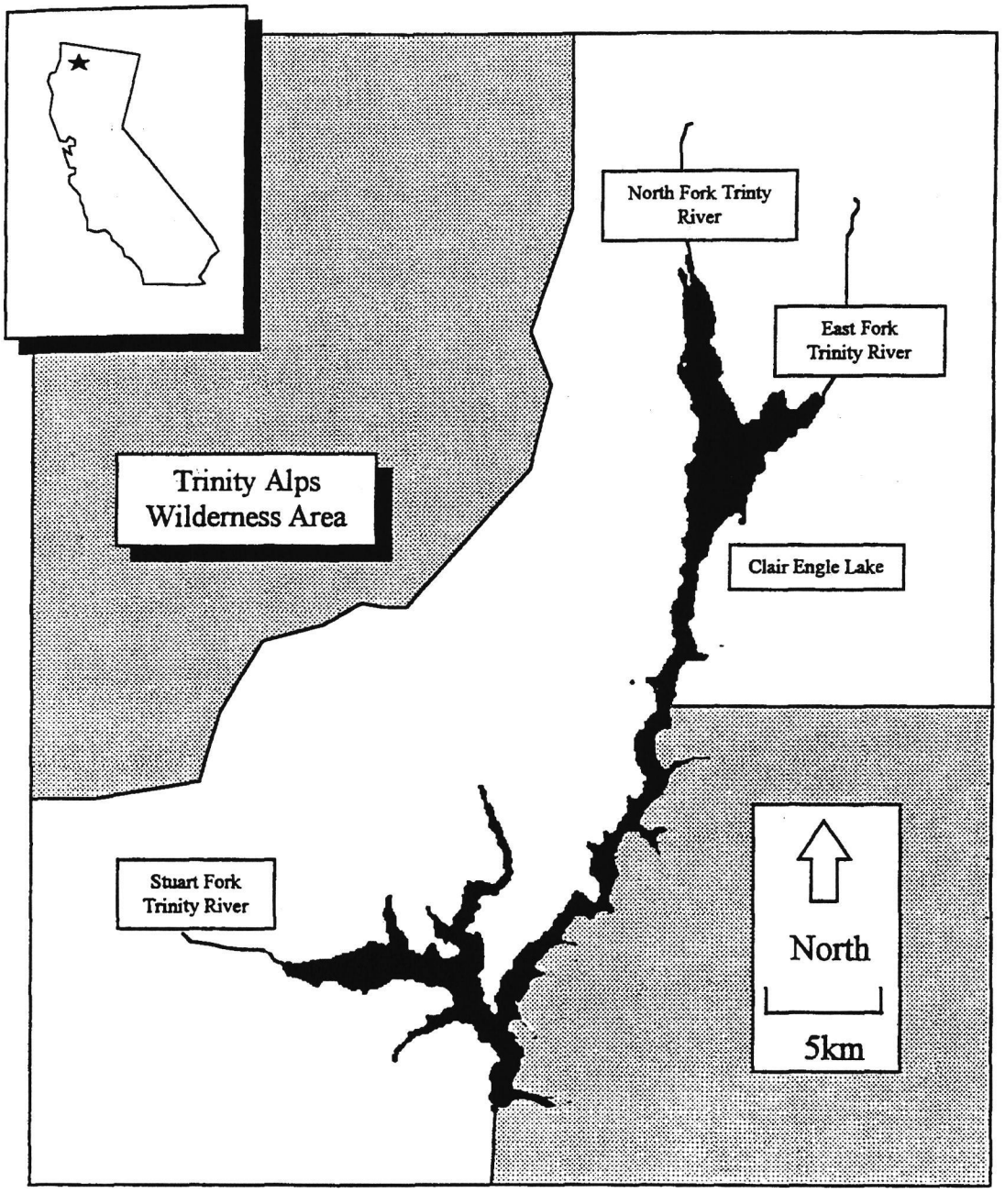


Figure 1. Approximate Location of Shasta Trinity Fisher Project Study Area in Shasta and Trinity Counties, California. Study Area Does Not Include the Shaded Regions (Trinity Alps Wilderness Area and the Southeast corner of figure).

public and privately owned land. Approximately 70% of private lands were commercial forest, about 9% of the land were reserves, and 21% were commercially unproductive (U.S.D.I. 1990). Land management practices have favored early seral communities (U.S.D.I. 1990). However, there are regions within the study area where no timber harvesting has occurred in the past 50 years. Thus, both early seral stage and late seral stage forests occur in the area.

In 1963, the Trinity and Lewiston Dams were built to provide water for irrigation, a stable supply of water, recreation, and power generation (U.S.D.I. 1990). The construction of the Trinity Dam resulted in the flooding of approximately 20,460 acres of meadowland and riparian zones forming Clair Engle Lake (U.S.D.I. 1990). This lake transected the study area.

METHODS

Forest Carnivore Distribution

Track-plate Surveys

Previous studies have shown that sooted aluminum track-plates are appropriate for detecting mammalian carnivores (Fowler and Golightly 1994, Golightly and Seglund in preparation). More specifically, Golightly and Seglund (in preparation) performed six track-plate surveys from 1992 to 1994 in the study area. It was determined from this research that mammalian carnivores were present at the study area and detected effectively using track-plates and a survey duration of 26 days (Golightly and Seglund in preparation). Fowler and Golightly (1994) also found that a survey duration of 22 days or longer maximized the probability of detecting fisher. Therefore, in locations where I did not detect fisher there was a higher probability that fisher were either not present or in low densities compared to locations where fisher were detected.

I placed stations by first locating the southern most end of the study area and the first mapped Forest Service road using a 1:24,000 U.S.G.S. topographic map. Then, I plotted the first station at the beginning of the road. After placing the first station, I used the protocol described below to systematically place stations across the landscape. At a fine scale, I placed stations (a single track-plate location as per Fowler and Golightly 1994) approximately 50 m from a road (roads were paths that a vehicle could travel with or without 4-wheel drive, with or without public access) (Figure 2). Stations were placed

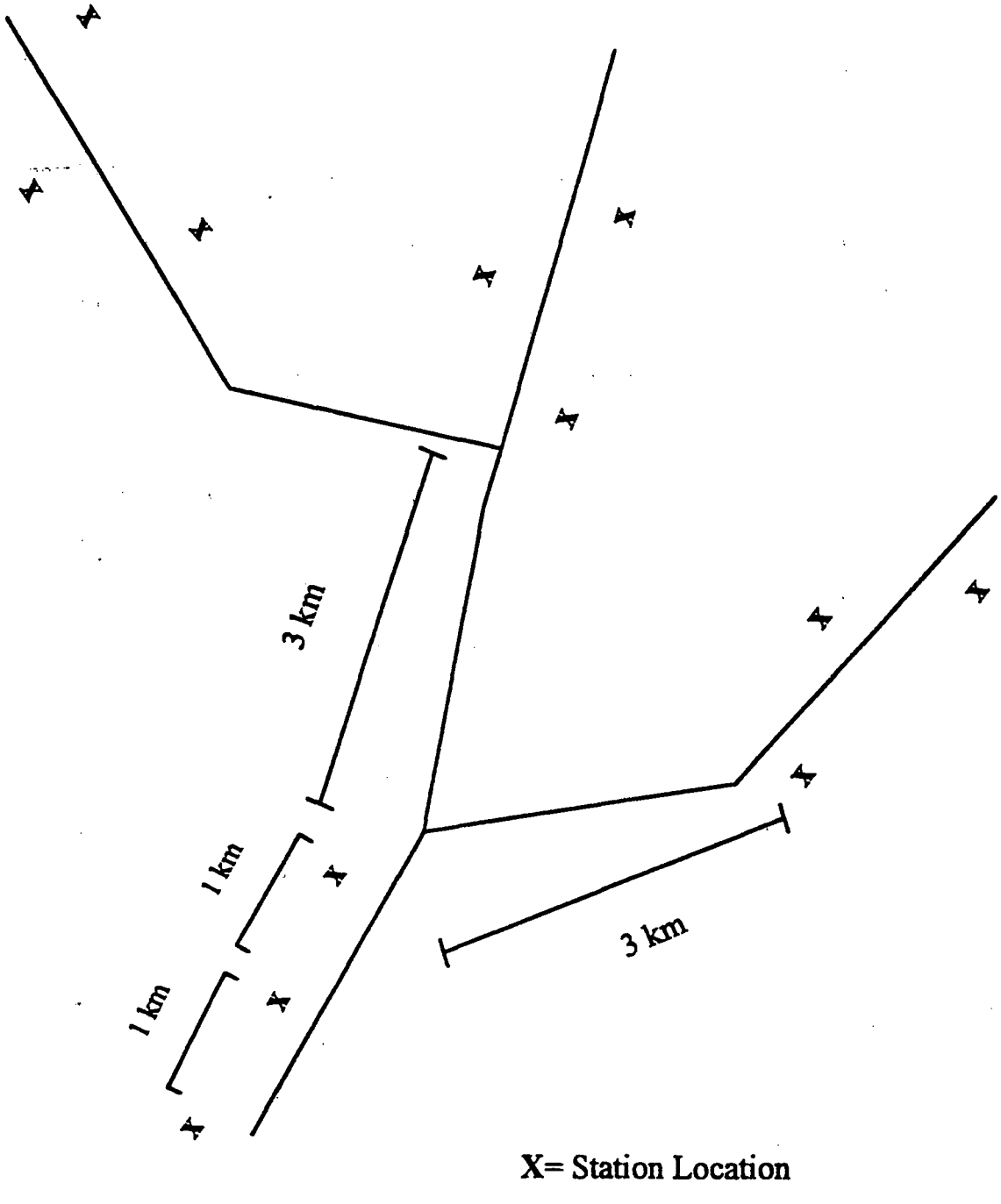


Figure 2. Portion of Study Area Illustrating Station (a single track-plate) and Segment (a series of three stations) Arrangement on the Landscape. All Stations Were Separated by 1 km. Each Segment Consisted of Three Stations. Segments Were Separated by 3 km. A Total of 42 Segments Were Placed Throughout the Landscape.

in drainages when possible as described by Golightly and Seglund (in preparation) to maximize the probability of detecting fisher. The consistent fine scale placement of stations may have been biased, but bias was minimized because of the relatively large geographic scale of the study. Golightly and Seglund (in preparation) also found that station placement in drainages improved other mammalian carnivore detection. I examined and rebaited every other day for a total of 26 days.

At the scale of the landscape, I placed groups of three stations, each separated by 1 km, across the landscape. Each group of stations (called segments) spanned a continuous distance of 2 km (Figure 2). A distance of at least 3 km separated the next lineal arrangement of stations (segments). The maximum distance that a series of stations could span while still remaining within a single unique landscape configuration was 2 km (as determined from orthophoto quads). Therefore, alternating segments with stations allowed for a more geographically extensive effort with track-plates throughout the study area, and potentially greater independence between positive detections.

During the summer of 1994, I divided the area into two regions, one on the east side and one on the west side of Trinity Lake. I examined twenty-four segments (72 stations) in the western region from 22 May 1994 to 16 June 1994 , and 18 segments (54 stations) in the eastern region from 6 July 1994 to 31 July 1994. Thus, a total of 42 segments (126 stations) were placed throughout the entire study area (Figure 3). I conducted a second survey during the Fall of 1994 (25 October 1994 to 19 November 1994) to assess the potential for seasonal variation in distributions. This survey was a nested subset of the summer survey. I selected every fourth segment from the summer

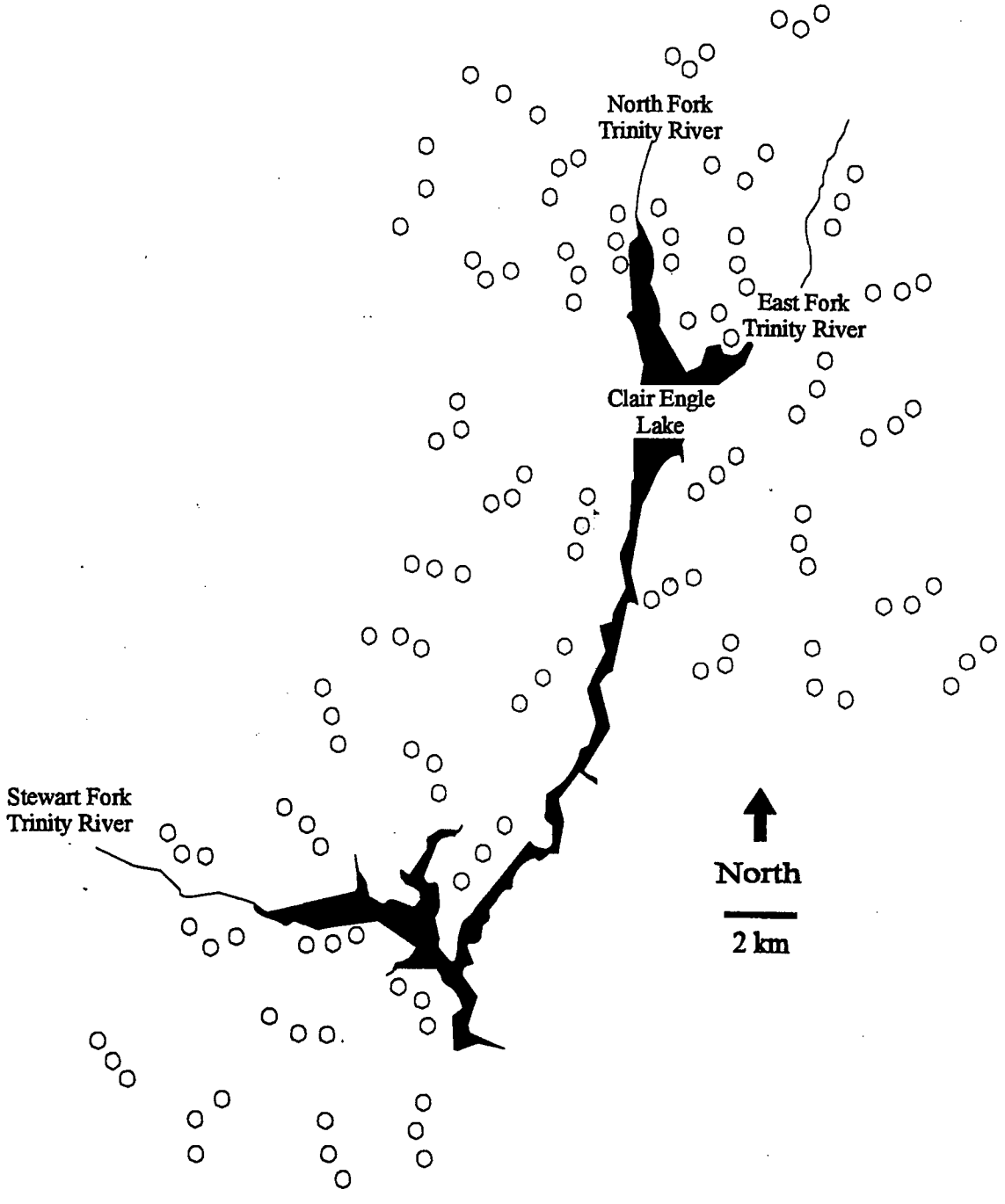


Figure 3. Illustration of Station and Segment Arrangement on the Shasta-Trinity National Forest Used For Examination of The Distribution of Mammlian Forest Carnivore and Landscape Habitat Use By Fisher. Each Circle Represents One Station. A Cluster of Three Circles Represents One Segment. Surveying was Conducted from May 1994 to August 1995.

survey for repetition. Sixteen segments (48) stations were resurveyed using this same protocol.

During the summer of 1995 I conducted a third survey. This survey was also a nested subset of the original summer 1994 survey. However, this survey was concentrated on the northeastern side of the study area so that other project objectives could be examined. All but two segments from the original northeastern region of the 1994 survey were retained. A total of 20 segments (60 stations) were surveyed from 23 July 1995 to 17 August 1995.

Landscape-Level Habitat Characteristics at Track-plate Locations

I used a raster based GIS to produce a map of station locations for collection of landscape characteristics. Stations were located in the field using one of two techniques. First, a Global Positioning System was used to determine a primary location (Trimble Scout Receiver, Model # 17319, Sunnyvale, Calif.). Second, compass bearings to known landmarks and elevation were measured and drawn onto a 1:24000, U.S.G.S. topographic map. Due to dense canopy cover and military interference with GPS-satellites signals GPS locations were not always reliable and differential corrections were not available for the GPS unit. Therefore, I used the GPS location only when it appeared reasonable compared to the mapped elevation and compass bearing. Locations were mapped using the Universal Transverse Mercator System (UTM) (Edwards 1969).

Current land cover maps derived from Landsat Thematic Mapper (TM) images were provided by the California Resources Agency. The images were classified by

Geographic Resources Solutions (Arcata, CA), and ground truthed by the U.S.D.A. Forest Service, Pacific Southwest Research Station, Fresno, CA (see Appendix A). These images consisted of 25 m x 25 m pixels and covered the entire study area. Five habitat categories based on the habitat and vegetation descriptions used in the California Wildlife Habitat Relationships System (see Mayer and Laudenslayer 1988) and 5 canopy cover categories (canopy cover was defined as the percent of canopy cover provided by trees on the 25 m x 25 m pixel) were provided from the landsat imagery (Table 1, Appendix A).

Using IDRISI 4.0 (Clark University, Worchester, MA), I centered a concentric buffer with an area of 3.14 km^2 on the middle station of each segment. This was the largest size buffer possible without overlap between neighboring segments. I measured landscape characteristics within this buffer using three different Geographic Information Systems (IDRISI 4.0, PC Arcinfo 6.1 [ERSI, Redding, CA], and Fragstats 2.0 [Oregon State University, Corvallis, OR]). Variables measured with IDRISI were the area (km^2) of each habitat and canopy type within the buffers. I obtained the length of road (m) of each category within the buffer by importing the buffers into PC Arcinfo and overlaying them on digitized road maps (see Table 1). High use road and moderate use roads were combined into one category because the density of these road categories was consistent across all buffers and combining these categories increased the power of statistical tests. Landscape variables measured within each buffer using Fragstats 2.0 were the number of habitat patches, the mean shape of patches (which was measure by comparing the overall patch shape to that of a square), average size of patches, the number of disjunct core areas, and the total core area (Table 1). I used the core area variable to determine if the

Table 1. Variables measured including habitat and canopy cover categories identified in a raster based GIS for the Shasta-Trinity Fisher Project study area in Shasta and Trinity Counties, May 1994 - August 1995 (see Appendix A for map accuracy).

WHR Habitat Classifications Used (Mayer and Laudenslayer 1988)

Douglas-fir - Greater than 50% canopy cover by conifers with Douglas-fir as dominant tree species.

Klamath Mixed Conifer, Ponderosa Pine, and Jefferey Pine - Greater than 50% canopy cover, may be dominated by pines or greater than 3 conifer species.

Mixed Hardwood, Mixed Hardwood Conifer - Greater than 25% canopy cover by hardwoods, but less than 50% canopy cover by conifers.

Shrub - Greater than 10% canopy cover, but less than 10% canopy cover from trees.

Barren - Areas within a vegetation dominated habitat that are devoid of vegetation.

Canopy Cover (By Trees) Categories (Mayer and Laudenslayer 1988)

1 1-25% (Sparse)
2 26-50% (Open)
3 51-75% (Moderate)
4 76-100% (Dense)

Landscape Characteristics (McGarigal and Marks 1994)

Number of habitat patches - the number of patches of contiguous cells with the same habitat identification in the landscape buffer.

Mean shape of habitat patches - an index of the average shape of habitat patches within the landscape. Patch shape was defined by the equation:

$$(0.25)E'/\sqrt{A}$$

where E' is equal to the amount of edge in the patch (defined by the of the perimeter of the patch) and A is equal to the amount of area of the patch. The average of these values for each patch within the landscape buffer was used as the mean shape of habitat patches

Mean size of habitat patches - average size of all habitat patches within the landscape buffer.

Number of core areas - the sum of the number of disjunct core areas contained within the landscape. Disjunct core areas were defined as the areas left after 100 m was removed from the edge of a habitat patch. The core area variable was used to determine if the habitat patches within a landscape can be characterized as being

Table 1 Continued. Variables measured including habitat and canopy cover categories identified in a raster based GIS for the Shasta-Trinity Fisher Project study area in Shasta and Trinity Counties, May 1994 - August 1995. (See Appendix A for map accuracy.) "Continued."

	influenced by edge effects (McGarical and Marks 1994). Habitat patches less than 3.0 hectares were not considered core areas because no area would be left after 100 m of edge was removed.
Total core area	the sum of the amount of disjunct core area (hectares) within the landscape buffer.
Road Classification	
High use roads	Paved roads open to the public year round.
Moderate use roads	Gravel or dirt roads that were open to the public year round.
Low use roads	Dirt roads not open to the public or open only seasonally.

patches within a landscape could be characterized as being influenced by edge effects (McGarigal and Marks 1994). I did not consider habitat patches less than 3.0 hectares in a measurement of core areas because no area would remain after all area within 100 m of the edge was removed. Unlike patch area, core area was affected by patch shape. Thus landscapes with several large patches may still lack enough core area to sustain edge-sensitive wildlife species (McGarigal and Marks 1994).

Landscape-Level Habitat Use at Fisher Rest Sites

In order to identify habitat used by fisher, I used radio telemetry to determine where fisher were resting and I identified stations that had been examined within fisher home ranges. This allowed for the measurement and comparison of landscape characteristics at fisher rest sites and track-plate locations within fisher home ranges that did not have fisher detections (thus, identifying rest site characteristics within the home range). More importantly, this allowed for the comparison of landscape habitat characteristics at fisher rest sites to track-plate locations where fisher were detected (these latter locations may have represented foraging and travel locations). The density of roads in buffers was not used for this analysis because the close proximity of stations to roads may bias differences when compared to rest site buffers which were not necessarily centered on roads.

RadioTelemetry

I trapped and radio collared fisher using techniques described by Seglund (1995). Modified Tomahawk live traps (Tomahawk Live Trap Company, Tomahawk, WI model #207) and handling cones were used to capture fisher (Seglund 1995). Fisher were immobilized using a combination of ketamine and diazepam (0.15-0.20 mg diazepam per 30-40 mg ketamine per kg body weight). While immobilized I weighed the fisher to the nearest 0.01 kg and body measurements were measured to the nearest 0.1 cm as per Seglund (1995) (Appendix B). Fisher were released at the capture site within one hour of my arrival. Previously radio collared individuals were recollared as necessary.

I located individuals with hand held yagi antennas (Model TR-4 receiver and RA-2A antenna, Telonics Telemetry-Electronics Consultants, Mesa, AZ). Due to rough terrain which caused severely inaccurate sources of the strongest signal, traditional triangulation techniques could not be used (Seglund 1995). Therefore, I followed the strongest radio signal to the actual resting location. A resting location was confirmed when the animal was sighted in the rest structure or the radio signal could be received with the antenna removed. Where we were unable to determine an exact resting structure, we did not use the location for habitat analysis. Individuals were located two to three times a week to provide independent locations (Seglund 1995). Resting locations were recorded with UTMs in the same manner that stations were plotted.

Home Range Calculation

Year round home range size was calculated for all fisher radio collared from 1992 to the winter of 1995. All telemetry locations, including those where I was close but unable to identify the rest structure, contributed to home range analysis. I calculated home range size with the program Telem (K. McKelvey, U. S. Forest Service, Pacific Southwest Research Station, Arcata, California) using the adaptive kernel method with the 95% kernel to describe home range (Worton 1989, Appendix C). Home range polygons were input into a GIS to produce a rasterized map of home ranges for each animal in the study area. Maps were used to identify which survey stations were within the boundaries of a fisher home range.

Landscape-Level Habitat Characteristics at Rest Sites and Track-plate Locations

Rest site locations obtained during the fall of 1994 and summers of 1993, 1994 and 1995 (same seasons as the 1994 and 1995 fall and summer surveys) were entered into a rasterized image. Because I did not conduct track-plate surveys during winter and there may be differences in habitat use by fisher during different seasons, I did not include winter rest sites in this analysis. Buffers with a 300 m radius (28.3 ha) were created around each resting location using IDRISI 3.0. I calculated the median size (419.98 ha) of habitat patches used by fisher for resting and the minimum patch size (1.25 ha) where fisher were detected to obtain the upper and lower bounds in which a buffer size could be. Then by generating several different buffer sizes I found the maximum buffer size that minimized overlap between buffers.

Station locations used in fisher rest site analyses were determined by overlaying a map of home ranges onto the map of stations. When a station was within the boundaries of a fisher home range, then that station was included in rest site comparison analyses. If a station did not fall into a home range then the station was not considered for further analysis. With the exception of road density, I measured the same variables as in the distribution analysis (Table 1) to compare landscape characteristics at rest site and station locations within the home range.

Data Analysis for Carnivore Distribution

To determine if the number of detections was independent of survey period I calculated a station detection ratio for each survey (the number of stations at which the species of interest was detected divided by the total number of stations available; Fowler and Golightly 1994). The detection ratio includes only the presence or absence of a species and not the frequency with which an animal may revisit or where multiple animals of the same species visit the same station. A contingency table was used to determine if the number of detections for each species were independent of season (Zar 1984). Independent data were pooled across surveys.

Species Interactions

To examine correlations between the detection of species at stations, a log linear analysis was performed using NCSS 6.1 (Hintze 1995). The log linear analysis identified potential interactions that may affect species distributions. For example, if gray fox were

detected more often than random chance at the same stations as ringtails, then this would be identified as a significant positive interaction. This analysis was performed at the individual station level and not the segment level because few segments had more than two species detected. A step-down Model-Search selection technique and Pearson's X^2 were used to select the most parsimonious and best fitting model (Hintze 1995).

Landscape-Level Habitat Analysis

I used logistic regression to develop predictive models of landscape characteristics for each species (Hosomer and Lemeshow 1989). A segment was considered to have a positive detection for a species when the species was detected at any station within a segment. For each segment the presence or absence of a detection was the dependent variable.

Before using logistic regression a correlation matrix was calculated and univariate statistics for each species were performed using NCSS 6.0 (Hintze 1995). To reduce redundancy when a set of variables were highly correlated ($r^2 \geq 0.60$), the variable within the set considered to be important to fisher, based on previous studies (Buck et al. 1994, Seglund 1995) was retained and other variables within that set were removed from further analysis (Hosomer and Lemeshow 1989, Pereira and Itami 1991, Stevens 1992, Manly et al. 1993). A stepwise procedure based on the Maximum Likelihood Ratio was used as a variable reduction technique for each species (Hosomer and Lemeshow 1989, Pereira and Itami 1991, Stevens 1992, Trexler and Travis 1993). Univariate statistics were then used to obtain an understanding of each variable's role in habitat selection.

A model chi-square for the logistic regression was used to test the overall fit of the model. Individual Chi-square values for each variable were used to determine if the slope of the estimated coefficient was significantly different from zero. Two further statistics were calculated: the odds ratio and Wald statistic (Hosomer and Lemeshow 1989, Trexler and Travis 1993). The odds ratio approximated how much more likely it is for the species of interest to be present at a segment with one unit of change in the given variable. For example, when looking at the presence of gray fox in relationship to Douglas-fir, if the estimated odds ratio was 3, then this indicated that for every increase of 1 km^2 of Douglas-fir within the segment buffer, the probability of getting a gray fox detection increased 3 times. The Wald statistic is the ratio of the parameter estimate to its standard error. The significance of this ratio was assessed by comparing it to a standard normal distribution. Values greater than 2 for the Wald statistic indicated the estimated coefficient was significantly different from zero and significantly influenced the model (Hosomer and Lemeshow 1989).

Logistic regression models were developed separately for the summer of 1994, the fall of 1994, and the summer of 1995 for detected species. Data were pooled across surveys when variables included in the model for a species were the same across each survey. Pooled data resulted in a greater number of segments with positive detections. In situations where sample sizes were too low for model development for each survey, the data were pooled if the proportion of detections did not vary significantly ($P < 0.05$) between surveys.

Data Analysis for Landscape-Level Habitat Use at Fisher Rest Sites

To further identify the landscape composition at fisher rest sites, I compared landscape characteristics within the buffers surrounding rest sites to that of stations without fisher detections. To determine if locations fisher used for resting differ from those used for foraging, and travel, I also compared landscape characteristics within the buffers surrounding rest sites to those of stations with fisher detections. For each of these comparisons, I used a two group Multivariate Analysis of Variance (Hotelling's T^2; Stevens 1992) with SPSS 6.1 (Advanced Version, SPSS, Chicago, Illinois). Each MANOVA was adjusted for unequal sample size using the least squares mean, but the arithmetic means were used for all other analyses.

Preliminary analyses were performed to reduce the number of variables used and to ensure that the assumptions of MANOVA were met. First, a correlation matrix was calculated using NCSS 6.0 (Hintze 1995). Redundant variables were removed using the same technique as the mammalian carnivore distribution analysis.

Data for each MANOVA were tested for equal covariance matrices and normality (Stevens 1992). A Box's M test was used to test for multivariate equality of covariance matrices and univariate Omnibus tests for each variable were used to infer multivariate normality. The amount of barren area, mean shape, and the amount of mixed hardwood were log transformed for each analysis to meet the assumptions of normality and equality of variances. Finally, with data sets that had small sample sizes, the variables were viewed graphically and with normal probability plots to determine if the assumptions were in fact met (Stevens 1992).

A concern that became apparent in reviewing the GIS was that the habitat at the study area was different on the east and west sides of the lake. On the west side of the lake, several fisher home ranges and detections occurred on the border of the Trinity Alps Wilderness Area. Therefore, the landscape buffers from the west side of the lake were dominated by more dense canopy closure and residual Douglas-fir stands, than the east side of the lake where there was more habitat alteration.

To determine if the data could be pooled between east and west sides of the lake, I used a MANOVA to compare landscape characteristics within rest site buffers between the two sides of the study area (with the Trinity River as the dividing line delineating the east and west sides of the study area). Also, studies have suggested that there may be variation in habitat use by fisher by sex and by individuals (Powell 1982, Arthur et al. 1989). Therefore, to determine if data could be pooled between individuals and between sex I performed two further MANOVA's for each side of the lake. Data were grouped by individuals and again by sex separately. For each side of the lake two MANOVAs were performed, one comparing landscape characteristics within rest site buffers between individuals (with the individuals as factors) and the other comparing landscape characteristics within rest site buffers between sexes (with sex as the factor). If landscape characteristics did not differ significantly between individuals and sexes then I pooled the data and used MANOVA's to compare landscape characteristics between stations and rest sites.

When a MANOVA comparing landscape characteristics between rest sites and stations was significant, I followed the test by an ANOVA and univariate tests. Univariate

tests ($\alpha = 0.05$) were preferred over multiple comparison procedures because they provided greater power for detecting differences with low sample sizes (Stevens 1992). When a MANOVA was not significant, no *post hoc* procedures were performed (Stevens 1992).

Assumptions and Limitations

The use of track-plates, while largely successful in detecting mammalian carnivores, has limitations. First, track-plates can identify habitat that forest carnivores use, but they do not necessarily indicate the quality of habitat. Demographic studies on each forest carnivore detected would need to be assessed in order to demonstrate habitat quality (Van Horne 1983). Secondly, it cannot be assumed that species have equal detectability using the track-plate technique. Some species may have greater or lower detectability. If this is so, comparison of habitat between different species will be dependent on adequate samples of each species. Finally, the lack of a fisher detection does not mean the area was not used by a fisher. It is possible that a fisher was present in the area and did not go to the station for many reasons (i.e., there was no motivation to obtain the bait, the distance or location of the station from the fisher precluded the fisher finding it). However, the probability of detecting fisher at track-plate locations has been assessed extensively by Fowler and Golightly (1994). With the appropriate duration for the survey, the probability of detecting a fisher if it is in the area can be maximized, and the resulting sample will be representative of the habitats that are used.

The issue of scale in sampling may also be viewed as a limitation in this study. My sample design was created to maximize fisher detections. Therefore, it is possible that the scale of the study, while at a landscape scale for fisher, may not have been a proper landscape scale for other species. Weins (1989) argued that each organism defines scale differently and therefore, landscape size should differ among organisms. Weins further suggested that the landscape scale may be at a spatial scale intermediate to a species home range and their regional distribution (Trani 1976, Hallberg and Trapp 1984, McGarigal and Marks 1994).

Ground truthing indicated that the GIS database poorly classified several habitat categories and one canopy cover category. In particular, the shrub, pine, and 50-75% canopy cover categories showed low accuracy. Ground truthing of the database was done with 200 vegetation plots over the 500km^2 study area. However, 5 habitat categories and 5 canopy cover categories were used. Plots used for ground truthing were not equally distributed among habitat types and therefore, fewer than 40 plots were used in the categories which had poor classification accuracy. Data collection for the 200 plots was difficult and this was the maximum number of plots that could be obtained over such a large area in rough terrain. Statistical tests involving variables with poor accuracy in their categorization should be viewed with caution.

RESULTS

Forest Carnivore Distribution

I detected eight mammalian carnivore species during each survey (Table 2). Raccoon (Procyon lotor), striped skunk (Mephitus mephitus), and spotted skunk (Spilogale gracilus) were detected at few segments (Table 2). Therefore, I excluded these species from further analyses.. The proportion of detections for black bear, fisher, gray fox, and ringtail did not vary significantly between surveys ($\chi^2 = 7.86$, df = 6, $P = 0.25$).

Species Interactions

I excluded ringtail from the log linear analysis due to low sample size of ringtail detections. Only black bear, fisher, and gray fox detections were used. The best model describing species interactions was a two way interaction between gray fox and black bear ($\chi^2 = 12.40$, df = 1, $P < 0.001$). Interpretation of residuals indicated a negative interaction, thus, gray fox were detected at stations where black bear were detected less than expected. However, the next model selected included a three way positive interaction between black bear, fisher, and gray fox. At stations where fisher were detected, black bear and gray fox had a high probability of being detected as well. However, the negative interaction between gray fox and black bear was still applicable at stations where fisher were not detected. This model was not significant at the 0.05 level

Table 2. Detection ratios calculated for carnivores during three surveys on the Shasta-Trinity National Forest, on Shasta and Trinity Counties. The summer survey of 1994 was conducted from 22 May 1994 to 16 June 1994 and from 6 July 1994 to 31 July 1994. The 1994 fall survey was conducted from 25 October 1994 to 20 November 1994. The summer survey of 1995 started on 23 July 1995 and Ended on 17 August 1995. (n = number of stations monitored)

	Detection Ratios (Number of Stations With Detections)		
Species	Summer 1994 (n = 126)	Fall 1994 (n = 48)	Summer 1995 (n = 60)
Black Bear	0.22 (27)	0.10 (12)	0.25 (31)
Domestic Cat	0.01 (1)	0.00 (0)	0.00 (0)
Fisher	0.13 (16)	0.15 (18)	0.18 (22)
Gray Fox	0.32 (40)	0.56 (70)	0.52 (65)
Raccoon	0.01 (1)	0.01 (1)	0.01 (1)
Ringtail	0.10 (12)	0.12 (15)	0.15 (18)
Spotted Skunk	0.06 (8)	0.04 (5)	0.00 (0)
Striped Skunk	0.05 (7)	0.04 (5)	0.04 (5)

($\chi^2 = 3.35$, df = 1, $P = 0.06$), but given the low power associated with a small sample size an alpha of 0.05 may be too conservative.

Landscape-Level Habitat Analysis

I used eleven landscape characteristics for the carnivore logistic regression models (Table 3). There were significant logistic regression models for black bear, fisher, and ringtail.

Black Bear. Black bear were detected in 26 of the 42 segments when all surveys were combined (Figure 4). During summer of 1994 and 1995 black bear were detected at 24 of the 42 segments and 2 additional segments had black bear detections during fall of 1994 that did not have them in the previous survey. The logistic regression model did not discriminate landscape variables differently between surveys. With data from all surveys pooled, the stepwise procedure resulted in a significant model ($\chi^2 = 14.34$, $P < 0.01$). Sites where black bear were detected had less area of 51-75% canopy cover and sixty-nine percent of the landscape buffers were classified correctly (Table 4, Appendix D). Four variables, the amount of area with 51-75% canopy cover, total core area, number of core areas, and low use road density were retained by the stepwise logistic regression analysis (Table 5). This model correctly classified sixty-nine percent of the landscape buffers.

Gray Fox. With all seasons combined, gray fox were detected in 32 of the 42 segments (Figure 4). During the summer of 1994, 24 of the 42 segments had gray fox detections, in the fall of 1994 6 segments had gray fox detections where they had not been detected previously and 2 additional segments had detections in the summer of 1995.

Table 3. Eleven landscape variables used in stepwise procedure for each carnivore detected on the Shasta-Trinity National Forest from May 1994 to August 1995. These variables were used to develop logistic regression models for each carnivore.

Retained Variables	Correlated Variables	r^2
Douglas-fir (km^2)	Shrub	-0.72
	76-100% Canopy Cover	0.84
Mixed Conifer\Pine (km^2)	26-50% Canopy Cover	0.91
Mixed Hardwoods\Mixed Hardwood Conifer (km^2)	None	
Barren (km^2)	None	
51-75% Canopy Cover (km^2)	None	
High-Moderate Road Density (km)	None	
Low Use Road Density (km)	None	
Number of Patches	Total Edge	0.94
Number of Core Areas	None	
Total Core Area (ha)	None	
Mean Patch Shape Index	None	

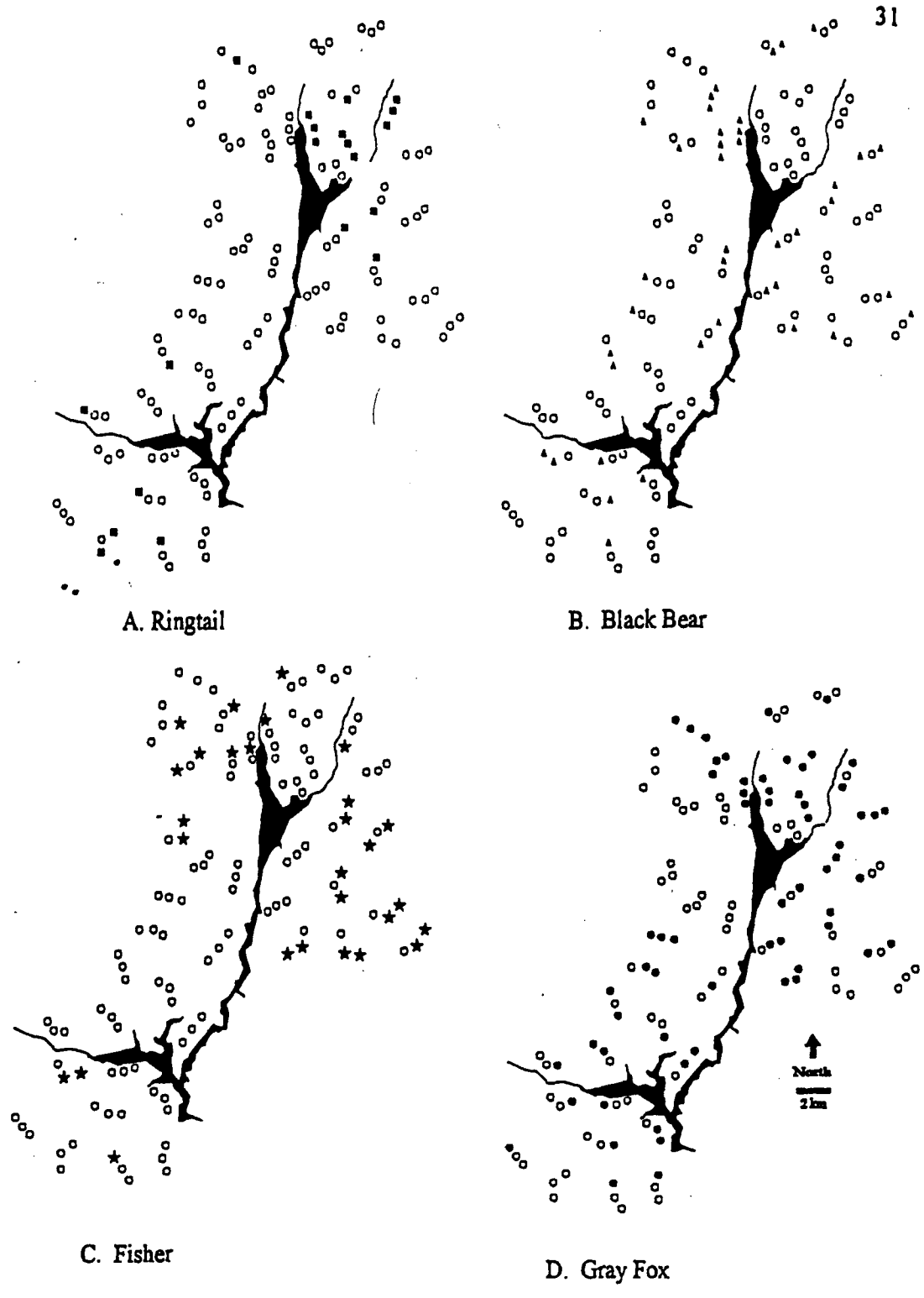


Figure 4. Figures 4A Through 4D Represent the Distribution of Four Forest Carnivores on the Shasta-Trinity National Forest Detected From May 1994 to August 1995. Filled Shapes Represent Locations Where Each Species Was Detected and Open Shapes Represent Locations Where the Species Was Not Detected.

Table 4. Results from t-tests comparing of 11 landscape habitat characteristics where Black Bear were detected versus where they were not detected from May 1994 to August 1995 on the Shasta-Trinity National Forest. Data were collected from a raster based GIS (n = Number of Segments).

	Detections Absent (n =16)		Detections Present (n = 26)			
Variable[a]	$\bar{x}$	SE	$\bar{x}$	SE	P-value	Test
Douglas-fir (km^2)	1.4	0.15	1.60	0.08	0.84	t-test
Klamath Mixed Conifer/Pine (km^2)	2.05	0.11	1.99	0.81	0.48	MWT
Mixed Hardwoods\Mixed Hardwoods Conifer (km^2)	1.83	0.01	1.62	0.10	0.15	MWT
Barren (km^2)	0.31	0.08	0.38	0.06	0.66	MWT
51-75% Canopy Cover (km^2)	1.83	0.07	1.59	0.02	0.02	t-test
High-Mod. Use Road Density (km)	5.02	0.98	5.04	0.67	0.88	t-test
Low Use Road Density (km)	7.96	1.38	8.98	0.94	0.57	MWT
Number of Patches	199.82	6.48	189.00	9.28	0.47	MWT
Number of Core Areas	22.52	1.12	24.09	1.22	0.21	t-test
Mean Shape Index	1.32	0.00	1.32	0.01	0.84	t-test
Total Core Area (km^2)	0.57	0.89	1.04	0.19	0.03	MWT

[a] See Table 1 for definitions of variables.
[b] Mann Whitney Two Sample Test

Table 5. Results from stepwise logistic regression with variables that discriminated between landscapes where Black Bear were detected and landscapes where Black Bear were not detected on the Shasta-Trinity National Forest from May 1994 - August 1995. Log odds ratios were adjusted for measurements in hectares by multiplying the coefficients by 0.01 to provide better interpretation of results (Lemeshow and Hosmer 1989). For graphical interpretation of significant variable see Appendix D.

Variable[a]	Coefficient Chi-square	P-value	Regression Coefficient	SE	Odds Ratio	Wald Statistic
51-75% Canopy Cover	-4.64	0.03	-4.27	1.98	0.96	-2.15
Total Core Area (km^2)	3.26	0.07	0.18	0.12	1.19	1.50
Number of Core Areas	2.25	0.14	0.13	0.08	1.14	1.63
Low use road density (km)	2.93	0.08	0.002	0.01	1.00	2.00

[a]See Table 1 for variable definitions.

Neither the logistic regression model nor univariate statistics successfully discriminated any landscape variables (Tables 6 and 7).

Ringtail. I detected ringtail in 13 of the 42 segments with all surveys combined (Figure 4). Seven segments had ringtail detections during the summer of 1994 and 2 additional segments had detections during the fall of 1994. The summer of 1995 resulted in 4 segments with ringtail detections that did not have them during previous surveys.

I could not assess logistic regression models for each survey due to a small number of detections during the fall of 1994 (n = 4) and the summer of 1995 (n = 4). Because the proportion of detections did not vary across seasons, the data were pooled. The logistic regression model with pooled data was significant ($\chi^2 = 7.62$, $P < 0.01$; 79% correct classification). The amount of core area was significantly lower where ringtail were detected than where they were not detected (Table 8; Appendix E).

Fisher. Fisher were detected in 17 of the 42 segments (Figure 4). Eleven segments had detections during the summer of 1994 and only 1 additional segment had a fisher detection during the fall of 1994. Five segments had additional fisher detections during the summer of 1995.

The logistic regression model with pooled data from all surveys was significant ($\chi^2 = 7.62$, $P < 0.01$). There was a greater amount of Douglas-fir, a greater amount of 51-75% canopy cover, and less barren area in landscape buffers where fisher were detected (Tables 9 and 10, Appendix F). Low use road density and number of disjunct core areas had *P*-values of 0.06 in the logistic regression model. While not significant at the 0.05 level, their inclusion in the model improved classification accuracy. There was a greater

Table 6. Results from t-tests comparing 11 landscape habitat characteristics collected from a raster based GIS of the Shasta-Trinity National Forest where Gray Fox were detected versus where they were not detected from May 1994 to August 1995.

	Detections Absent (N=10)		Detections Present (N=32)			
Variable[a]	$\bar{x}$	SE	$\bar{x}$	SE	P-value	Test
Douglas-fir (km^2)	1.66	0.28	1.60	0.01	0.81	t-test
Klamath Mixed Conifer\Ponderosa Pine (km^2)	2.13	0.23	1.99	0.12	0.76	MWT[b]
Mixed Hardwood Conifer\ Mixed Hardwood (km^2)	1.67	0.20	1.72	0.06	0.57	MWT
Barren (km^2)	0.35	0.09	0.35	0.01	0.75	MWT
51-75% Canopy Cover (km^2)	1.80	0.06	1.67	0.06	0.14	MWT
High-Moderate Use Road Density (km)	4.49	1.26	5.20	0.64	0.44	MWT
Low Use Road Density (km)	8.32	1.35	8.60	0.96	0.88	t-test
Number of Patches	190.00	10.15	194.70	7.16	0.74	MWT
Number of Core Area	22.11	1.40	23.80	1.01	0.67	MWT
Mean Shape Index	1.31	0.01	1.32	0.01	0.59	t-test
Total Core Area (km^2)	0.87	0.14	0.34	0.15	0.24	MWT

[a] See Table 1 for Definitions of Variables.
[b] Mann Whitney Two Sample Test

Table 7. Results from stepwise logistic regression with variables that discriminated between landscapes where Gray Fox were detected and landscapes where Gray Fox were not detected on the Shasta-Trinity National Forest from May 1994 - August 1995. Log odds were adjusted for measurements in hectares by multiplying the coefficients by 0.01 to provide better interpretation of results (Lemeshow and Hosmer 1989).

Variable[a]	Coefficient Chi-Square	P-value
Douglas-fir (km^2)	0.78	0.38
Klamath Mixed Conifer/Ponderosa Pine (km^2)	1.46	0.23
Mixed Conifer Hardwood/Mixed Hardwood (km^2)	1.29	0.26
51-75% Canopy Cover(km^2)	0.17	0.68
Barren (km^2)	1.44	0.23
Low Use Road Density (km)	0.12	0.73
Number of Patches	0.12	0.74
Number of Core Areas	0.16	0.67
Mean Shape Index	0.03	0.87
Total Core Area	1.68	0.20

[a] See Table 1 for definitions of variables.

Table 8. Results from t-tests comparing 11 landscape habitat characteristics where Ringtail were detected versus where they were not detected from May 1994 to August 1995 on the Shasta-Trinity National Forest. Data were collected from a raster based GIS (n = number of segments). The number of core areas was the only significant variable in the logistic regression model (χ^2 =4.00, p = 0.04).

	Detections Absent (n = 13)		Detections Present (n = 29)			
Variable[a]	$\bar{x}$	SE	$\bar{x}$	SE	P-value	Test
Douglas-fir (km^2)	1.64	0.13	1.56	0.09	0.59	t-test
Klamath Mixed Conifer/Pine (km^2)	2.02	0.14	2.03	0.14	0.55	MWT[b]
Mixed Hardwood Conifer/ Mixed Hardwood (km^2)	1.66	0.01	1.81	0.01	0.34	t-test
Barren (km^2)	0.34	0.05	0.36	0.13	0.48	t-test
51-75% Canopy Cover (km^2)	1.69	0.01	1.71	0.01	0.95	MWT
High-Mod. Use Road Density (km)	5.00	0.69	5.13	1.00	0.92	MWT
Low Use Road Density (km)	8.89	0.89	7.64	1.72	0.49	t-test
Number of Patches	191.67	7.20	199.77	9.49	0.54	MWT
Number of Core Areas	23.17	1.00	24.00	1.63	0.67	t-test
Mean Shape Index	1.32	0.00	1.32	0.01	0.65	t-test
Total Core Area (km^2)	1.01	0.16	0.46	0.09	0.04	t-test

[a] See Table 1 for Definitions of Variables.
[b] Mann Whitney Two Sample Test

Table 9. Results from t-tests comparing 11 landscape habitat characteristics where fisher were detected versus where they were not detected from May 1994 to August 1995 on the Shasta-Trinity National Forest. Data were collected from a raster based GIS (n = number of segments).

	Detections Absent (n = 16)		Detections Present (n = 26)			
Variable[a]	$\bar{x}$	SE	$\bar{x}$	SE	P-value	Test
Douglas-fir (km^2)	1.48	0.11	1.82	0.14	0.05	t-test
Klamath Mixed Conifer/Pine (km^2)	2.03	0.16	2.01	0.11	0.94	t-test[b]
Mixed Hardwood Conifer/ Mixed Hardwood (km^2)	1.74	0.01	1.66	0.10	0.41	MWT[c]
Barren (km^2)	0.36	0.06	0.34	0.08	0.44	t-test
51-75% Canopy Cover (km^2)	1.62	0.06	1.82	0.07	0.05	t-test
High-Mod. Use Road Density (km)	4.37	0.77	5.25	0.83	0.59	MWT
Low Use Road Density (km)	7.34	1.14	9.96	0.96	0.02	MWT
Number of Patches	197.00	7.25	189.00	9.66	0.50	t-test
Number of Core Areas	23.34	1.01	23.50	1.49	0.86	t-test
Mean Shape Index	1.31	0.00	1.31	0.01	0.89	t-test
Total Core Area (km^2)	0.90	1.75	0.75	0.15	0.64	MWT

[a] See Table 1 for Definitions of Variables.
[b] T-test for Unequal Variance Used.
[c] Mann Whitney Two Sample Test

Table 10. Results from stepwise logistic regression with variables that best discriminated between landscapes where Fisher were detected and landscapes where fisher were not detected on the Shasta-Trinity National Forest from May 1994 - August 1995. Log odds were adjusted for measurements in hectares by multiplying the coefficients by 0.01 to provide better interpretation of results (Lemeshow and Hosmer 1989). For graphical interpretation of significant variables see Appendix F.

Variable[a]	Coefficient Chi-Square	P-value	Regression Coefficient	SE	Odds Ratio	Wald Statistic
Douglas-fir (km^2)	4.57	0.03	2.74	1.28	1.03	2.14
51-75% Canopy Cover(km^2)	5.30	0.02	5.17	2.25	1.05	2.30
Barren (km^2)	4.83	0.03	4.51	2.05	1.05	2.20
Low Use Road Density (km)	3.51	0.06	0.17	0.09	1.18	1.89
Number of Core Areas	3.43	0.06	0.22	0.12	1.25	1.83

[a] See Table 1 for definitions of variables.

density of low use roads and fewer disjunct core areas in landscape buffers where fisher were detected (Tables 9 and 10). Seventy four percent of the landscape buffers were correctly classified. Separate stepwise procedures for each survey resulted in the selection of the same variables, consequently pooling of data from each survey was appropriate.

Douglas-fir was positively correlated with 76-100% canopy cover ($r^2 = 0.84$) and negatively correlated with shrub ($r^2 = - 0.72$). Therefore, landscape buffers where fisher were detected were characterized by stands classified as Douglas-fir with dense canopy cover and less than average shrub patches.

Comparison of Fisher Rest Sites to Track-Plates Within the Home Range

Seventy-four rest site locations and 79 station locations were used to compare landscape habitat characteristics at rest sites to station locations. Of the 79 stations used, 27 had positive detections and 52 lacked detections. Nine landscape variables were used for this analysis (Table 11).

There was a significant difference between rest site buffers on each side of the lake ($F = 8.70$, $df = 9,132$, $P < 0.001$), indicating that rest sites on the east and west side of the lake could not be pooled. When grouped by individuals, non-significant results were obtained for the east side ($F = 1.38$, $df = 27,199$, $P = 0.11$) and west side ($F = 1.42$, $df = 18,82$, $P = 0.15$) of the lake indicating that landscape characteristics at rest site buffers could be pooled across individuals for each side of the lake. Likewise, there was no difference in landscape characteristics between sexes on the east ($F = 1.74$, $df = 9,30$, $P = 0.12$) or between sexes on the west side ($F = 1.42$, $df = 9,15$, $P = 0.26$) of the lake.

Table 11. Nine landscape variables used to compare fisher rest site locations to stations where fisher were and were not detected on the Shasta - Trinity National Forest from May 1994 to August 1995.

Retained Variables	Correlated Variables	r^2
Douglas-fir / White Fir (km^2)	Shrub	-0.61
	Pine	0.61
	Total Edge	-0.75
	25-74% Canopy Cover	0.61
	76-100% Canopy Cover	0.73
Mixed Conifer (km^2)	None	
Mixed Hardwoods\Mixed Hardwood Conifer (km^2)	None	
Barren (km^2)	1-24% Canopy Cover	-0.70
51-75% Canopy Cover (km^2)	None	
Number of Patches	Total Edge	0.94
Number of Core Areas	None	
Total Core Area (ha)	None	
Mean Patch Shape Index	None	

For further comparisons of landscape characteristics at rest site buffers to station buffers, I used a two group MANOVA with a randomized block design where the side of the lake where a location occurred was a blocked factor. This allowed for each analysis to be completed with one test while controlling for differences in habitat between lake sides.

There was a significant difference between landscape characteristics within fisher rest site buffers when compared to buffers at stations where fisher were not detected ($F = 7.68$, $df = 1, 122$, $P = 0.001$). The amount of 50-75% canopy closure ($F = 7.68$, $df = 1,122$, $P = 0.01$) and the number of disjunct core areas ($F = 11.52$, $df = 1,122$, $P < 0.001$) differed significantly between sites where fishers were detected and where they were not detected. On the east side of the lake, rest sites had more area of 50-75% canopy cover and fewer number of core areas than stations where fisher were not detected (Table 12; Appendix G). On the west side of the lake, *post hoc* univariate tests results indicated a greater amount of Douglas-fir, fewer disjunct core areas, less barren area, and less mixed conifer habitat at fisher rest sites (Appendix H).

There was no significant difference between landscape characteristics within rest site buffers and station buffers that had positive fisher detections ($F = 1.57$, $df = 9,89$, $P = 0.14$). However, only 9 stations on the west side of the lake had positive fisher detections and 25 on the east. Therefore, power to detect differences may have been low.

Table 12. Results from t-tests comparing landscape characteristics within Fisher rest site buffers and station buffers where fisher were not detected from May through August 1994 and 1995 on the Shasta-Trinity National Forest in Shasta and Trinity Counties, California. Analyses were conducted separately for the east and west side of Trinity Lake. For graphical interpretation of significant variables see Appendices G and H.

	West Side					East Side				
	Rest Site Locations (n = 25)		Detections Absent (n = 24)			Rest Site Locations (n = 48)		Detections Absent (n = 28)		
Variable	$\bar{x}$	SE	$\bar{x}$	SE	P-value	$\bar{x}$	SE	$\bar{x}$	SE	P-value
Douglas-fir / White Fir (ha)	12.9	0.45	7.96	0.73	<0.001	9.28	0.51	10.71	0.69	0.100
Mixed Conifer (ha)	2.56	0.20	3.75	0.26	<0.001	3.46	0.19	3.26	0.27	0.528
Hardwoods (ha)	2.57	0.31	2.74	0.39	0.992[1]	2.74	0.33	2.52	0.31	0.966[1]
Mixed Hardwood Conifer (ha)	5.52	0.26	5.88	0.33	0.987	6.15	0.25	5.65	0.32	0.218
Barren (ha)[1]	0.56	0.12	1.85	0.41	0.019[1]	1.34	0.24	0.65	0.15	0.144[1]
51 - 75% Canopy Closure (ha)	8.09	0.30	7.88	0.58	0.732	8.84	0.39	6.98	0.28	<0.001
Mean Shape Index	0.13	0.01	0.13	0.03	0.833[1]	1.36	0.01	1.37	0.00	0.385[1]
Number of Core Areas	2.84	0.21	3.71	0.30	0.021	2.71	0.21	3.61	0.31	0.015
Total Core Area (ha)	0.54	0.92	0.37	0.12	0.279	0.91	0.29	0.55	0.14	0.361

[1] Mann Whitney U Test Performed for Univariate Comparisons. Data were Log Transformed for Multivariate Procedures.

DISCUSSION

Forest Carnivore Distribution

The logistic regression models for black bear and ringtail suggested that my field sample design could be used to obtain the distribution of these species in reference to fisher. However, survey designs specific to each species may improve habitat models.

My analysis minimized the limitations of the track-plate technique in regards to habitat quality and species detectability. Logistic regression models of mammalian carnivore distribution were developed for each species separately and not compared across species. The log linear analysis assessed potential interactions between species that may have influenced species detectability. For example, detection of fisher at a track-plate increased the probability of detecting gray fox and black bear.

Species Interactions

Studies of species distribution rarely assessed the impact that species interactions had on distribution (Adler 1985, Harrison et al. 1989, Gese et al. 1996). Interactions between species with similar ecologies probably affected distribution and habitat use (Adler 1985, Harrison et al. 1989). It may be difficult to distinguish why these interactions occurred. In my study, it is possible that the observed relationships were influenced by habitat characteristics at track-plate locations. For example, at locations where fisher were detected there may have been a greater diversity of prey or other food

items and therefore, more diversity of mammalian carnivores. An intraspecific behavioral interaction may have influenced correlations in species detections (Alder 1985). Habitat analyses performed for each species may lend insight into the character of the observed significant interactions.

Landscape-Level Habitat Analysis

Black Bear. Black bear are typically a generalist species using both disturbed and non-disturbed forests. Several studies have showed that black bear exhibit variation in habitat use, social behavior, and reproduction within and among regions of the United States (Piekielek and Burton 1975, Reynolds and Beecham 1977). In the Western United States, black bear distribution was associated primarily with food distribution and the distribution of conifer habitat types (Piekielek and Burton 1975, Jonkel 1962, Reynolds and Beecham 1977, Hellgren 1993). Reynolds and Beecham (1977) noted that black bear distribution varied seasonally along an elevation gradient in Idaho. This elevation gradient was correlated with the ripening of berries and availability of other food sources.

In California on the Shasta-Trinity National Forest, Kelleyhouse (1975) found that black bear used early seral stage stands and landscapes with a greater diversity of habitat. Theoretically, habitat diversity within black bear summer home ranges favors cub survival by reducing the length of foraging expeditions during the first year of life. Kelleyhouse (1975) also found seasonal/elevation variation in habitat use and that recently logged areas were of limited seasonal value to black bears. However, mixed conifer forest habitat was used continually. Kelleyhouse (1977) hypothesized that the black bear population at the

study area was likely to be adversely affected by large-scale logging operations. Finally, Kellyhouse found that low elevation habitat patches that were selectively cut and less than 75% canopy closure were not used by black bear because the understory lacked species diversity for foraging.

At the scale of my analysis, only one habitat variable was significant (51-75% canopy cover) for black bear. Habitat patches with 51-75% canopy cover were representative of selective cuts and surveying in my study occurred within the "low elevation" classification of Kelleyhouse (1977). Thus, my observations are consistent with those of Kelleyhouse (1977). Unfortunately, the landscape measurements used in my study may not be important to black bear. Sampling at a different scale or measuring other landscape characteristics may have improved the analysis for black bear.

Gray Fox. Gray fox are considered a generalist species (Hallberg and Trapp 1984, Klenner 1987, Harrison 1993). In the western United States, few studies have assessed habitat use or distribution of gray fox. Hallberg and Trapp (1984) found that gray fox in Yolo County, California traversed all habitat types within a given region when vegetative cover was abundant. They also found that riparian corridors were important features to gray fox movement in regions where agricultural development limited available habitat. The distribution of gray fox was also influenced largely by prey availability (Trani 1976, Harris 1981, Harrison 1993).

Gray fox, similar to many canids, can adapt to a variety of environmental situations and food types (Hallberg and Trapp 1984, Harrison 1993). The use of forest types by gray fox compared to availability was not significant in the California (Haroldson and

Fritzell 1984). This was attributed to a high degree of habitat diversity at the study area, all of which were used by gray fox (Haroldson and Fritzell 1984). At the study area, gray fox were detected in many types of landscapes. The gray fox flexibility in habitat use may allow it to use more regions of the study area because the forest is characterized by patchiness. Thus, gray fox may be present everywhere at the study area. However, the log-linear analysis indicated that gray fox were not detected in locations where black bear were detected. This suggested that at the study area the distribution of generalists species such as, gray fox and black bear may be influenced by biological factors and not necessarily habitat alone.

Ringtail. Ringtail are distributed throughout the western and southern United States, and northern Mexico (Belluomini and Trapp 1984, Chevalier 1984). They are associated with a diversity of habitat types including scrub vegetation, oak woodland, deserts, and forested mountains (Belluomini and Trapp 1984, Chevalier 1984, Callas 1987). On a fine scale, ringtail have been known to inhabitat riparian corridors with second and third order streams (Grinell et al. 1937, Callas 1987). Ringtail have been reported to use rock crevices, hollow trees, brush piles and buildings as den sites (Fry 1926, Trapp 1978, Orloff 1980, Toweill and Teer 1981).

Callas (1987) found that ringtail used specific features within the landscape, and avoided clear cut and shrub stage habitats that lacked adequate den sites in the form of trees or snags. Ringtail utilized other forest types, besides clear cuts and shrub habitat, in proportion to their area (Callas 1987). My study area was characterized by regions with a greater degree of patchiness resulting from years of varied timber harvesting practices. I

detected ringtail in regions within the landscape that had less core area. These regions were also characterized by more edge which may be associated with a greater diversity of food items which is essential for adult female survival during reproduction.

Landscape-Level Habitat Use By Fisher

Several landscape characteristics appeared to be important to fisher at the study area. Fisher were detected in and rested in areas dominated by late successional stage Douglas-fir forests, with less fragmentation and less mixed conifer stands than other regions within their home range and the study area.

The presence of fisher in landscape buffers with Douglas-fir habitat and high canopy cover values was indicative of riparian vegetation. On the STNF the timber industry has been required by law to preserve buffers around streams and rivers (U.S.D.I. 1994). The size of these buffers varied depending on the type of land designation, stream order, soil type, and rock type (U.S.D.I. 1994). Buffers on the STNF varied from 30.5 m (100 ft) along intermittent streams with granitic soils to 182.8 m (600 ft) along fish bearing streams. Some buffers along fish bearing streams were larger than 182.2 m when the top of the associated inner gorge was a greater distance. Consequently, riparian habitat was characterized by residual Douglas-fir stands with high crown cover and a dense understory of Dogwood and Vine Maple trees. Seglund (1995) suggested that these riparian characteristics were important for fisher because they provided broken tops, snags, and downed logs which characterized fisher rest sites on the STNF (Seglund 1995). Late stage successional forests were described by Buskirk and Powell (1994) as having a

diversity of tree sizes and shapes, light gaps, dead and downed woody debris and multi-storied canopy closure. They argued that these conditions led to increased vertical and horizontal forest complexity which in turn provided three important features to fisher; 1) increased prey density, 2) increased prey vulnerability to fisher and, 3) structure that provided natal and maternal dens, as well as, resting sites. These conditions may have been important in defining resting and foraging locations that fisher used (deVos 1951, Kelly 1977, Buck et al. 1994, Buskirk and Powell 1994).

Seglund (1995) and Buck et al. (1994) found that fisher used habitat with a component of shrub cover. The landscape analysis I conducted was consistent with Seglund (1995) and Buck et al. (1994). The negative correlation of Douglas-fir habitat with shrub did not mean that habitat classified as Douglas-fir was devoid of shrub. At a microsite scale, there may have been a shrub layer present within the stand that the Landsat imagery did not detect. In fact, riparian vegetation at the study area often had some shrub component present.

Fisher were detected in areas with fewer barren patches. Both the rest site comparison to stations where fisher were not detected and the logistic regression had significant negative results for this variable. Barren areas represented habitat with little vegetative growth, such as clear cuts, roads, (or other human disturbance) and meadows. Several studies indicated that fisher were negatively influenced by clear cut edges (Clem 1977, Leonard 1980, Buck 1982, Kelly 1977). Raphael and Rosenburg (1986) found that the frequency of fisher occurrence decreased sharply when greater than 50% of a forest stand adjoined a clear cut. It has been suggested that fisher prefer edge habitats where

prey diversity was high, but not abrupt edges (Kelly 1977, Johnson 1984, Heinemeyer 1993). Abrupt edge was typical of clear cuts, grasslands, and rocky slopes; all were present at the study area and were included in the barren habitat category.

The inclusion of road density in the logistic regression distribution model indicated that where fisher were detected, there was a greater than average density of low use roads. The study area has been subject to timber harvesting and mining since the 1820's (U.S.D.I 1990). Therefore, the study area was characterized as having an intense network of roads (with varying degrees of use). Heinemeyer (1993) suggested that fisher crossed forest roads and that low-use roads were not a barrier to animal movement. Heinemeyer (1993) also suggested that mortality increased in areas with more roads due to automobile collisions with fisher. Because low use roads were characterized by minimal human activity, it was also possible that the inclusion of this variable was a response to human activity. Fisher may not have used portions of the landscape that were dissected by moderate to high use roads. The significance of this variable may be indicative of the potential impact of roads on fisher mortality at the study area. Further research needs to be directed at establishing the impact of roads on fisher.

The inclusion of the number of disjunct core areas in the logistic regression distribution model for fisher was very important. Several studies have suggested that fisher prefer forests with continuous canopy cover and avoid openings (deVos 1952, Coulter 1966, Kelly 1977, Roy 1991, Jones 1991). Raphael and Rosenburg (1986) hypothesized that fisher were "area sensitive" and that the occurrence of fisher was highly correlated with stand size. Fewer disjunct core areas in buffers where fisher were detected

indicated that there were more contiguous patches within these buffers. The significance of the number of disjunct core areas in the logistic regression distribution model and rest site analysis may imply that fisher on the STNF used large contiguous tracts of land. These tracts may be buffered from outside disturbance which would be consistent with Seglund (1995). However, while the amount of total core area was greater at rest sites and track-plate locations where fisher were detected than where they were not detected, this variable was not statistically significant in any analysis. This could be due to low power, or it could be the result of measuring core area using a raster based GIS. With raster based GIS's, the amount of core area can be difficult to measure due to individual pixels that have been misclassified within the patch. These pixels were not included in the number of core areas variable.

Fisher Rest Sites and Positive Detections Comparisons

Fisher may use different types of habitat depending on the type of activity they are engaged in (Buck et al. 1994, Jones 1991, Heinemeyer 1993). In particular, Jones (1991) and Heinemeyer (1993) found that fisher appeared to use a broader range of habitats for foraging than for resting. Arthur et al. (1989) also found that in Maine active fisher used a wider variety of habitat types than resting fisher. However, my results indicated that there was no difference between resting and track plate locations at the study area. The lack of significance between rest sites and track plate locations may have been the result of three scenarios; 1) low power, 2) track plate locations were not necessarily representative of

locations that fisher used for travel, or 3) fisher may in general use the same type of habitat for all activities.

Management Recommendations

Fisher distribution during the summer was not similar to gray fox, black bear, or ringtail. Each species was either detected in a different landscape configuration than fisher or was not distributed with regard to any the landscape features measured. It has been suggested that ringtail utilize similar habitats as fisher (Schempf and White 1977). Given my results, fisher may not be a good indicator species for ringtail. For example, if the landscape was being managed specifically for fisher based on the results of this study, then it is possible that the amount of core area in the landscape may change positively for fisher but could be changed negatively for ringtail. This can also vary at different scales (e.g., fisher and ringtail utilize similar micro-habitat for resting). Also, the Management Indicator Species may impair the generalists species by increasing competition in habitats with high prey diversity.

My results suggested that habitat used by fisher at the study area may have some similar components to Riparian Reserves and Late-Successional Reserves under the Northwest Forest Plan (U.S.D.I. 1994). In fact, three fisher home ranges fell within areas defined as Late-Successional Reserves close the Shasta-Trinity Wilderness area. To manage for fisher, sites classified as Late- Successional on the STNF with Douglas-fir as the dominate canopy species should be maintained with dense canopy closure

(>50% canopy cover), minimized road activity, and complex forest structure. Likewise, corridors connecting late successional stands where fisher are known to be present should be maintained with similar habitat characteristics as the stand itself. Roads within these reserves should be closed at least seasonally. Roads used for temporary purposes such as, timber harvesting or controlled burns, should be permanently closed once the activity is complete. It is unclear how further habitat alteration at the study area may impact fisher on the STNF and, therefore, research should continue to closely monitor fisher.

REFERENCES CITED

Adler, G. H. 1985. Habitat selection and species interactions: an experimental analysis with small mammal populations. Oikos 45:380-390.

Arthur, S. M., W. B. Krohn, and J. R. Gilbert. 1989. Habitat use and diet of fisher.J. Wildl. Manage. 53:680-688.

Arthur, S. M., T. F. Paragi, and W. B. Krohn. 1993. Dispersal of juvenile fisher in Maine. J. Wildl. Manage. 57:868-874.

Aubry, K. B., and D. B. Houston. 1992. Distribution and status of the fisher in Washington. Northwest Nat. 73:69-79.

Belluomini, L. A. 1983. Ringtail distribution and abundance in the Central Valley of California. M. S. Thesis, Calif. State Univ., Sacramento. 57pp.

_____, and G. R. Trapp. 1984. Ringtail distribution and abundance in the Central Valley of California. Pages 906-914 *in* R.E. Warner and K.M. Hendrix, editors California Riparian Systems. Univ. of Calif. Press, Los Angeles.

Block, W. M., and L. A. Brennan. 1993. The habitat concept in ornithology. Current Ornithol. 11:35-91.

Buck, S. G. 1982. Habitat utilization by fisher (Martes pennanti) near Big Bar, California. M.S. Thesis, Humboldt State University, Arcata. 55pp.

_____, C. Mullis, A.S. Mossman, I. Show, and C. Coolahan. 1994. Habitat use of fishers in adjoining heavily and lightly harvested forests. Pages 368-376 *in* S.W. Buskirk, A.S. Harlstad, M.G. Raphael, and R.A. Powell, editors. Martens, Sables, and Fishers. Cornell University Press. Ithaca, New York. 484pp.

Buskirk, S. W., and Powell, R. A. 1994. Habitat ecology of fishers and American martens. Pages 283-296 *in* S. W. Buskirk, A. Harestad, M. Raphael, editors. Biology and conservation of martens, sables, and fisher. Cornell University Press, Ithaca. 484pp.

Callas, R. 1987. Ringtail den and habitat use in Northwestern California. M.S. Thesis, Humboldt State Univ. 58pp.

Chevalier, C. D. 1984. Water requirements of free-ranging and captive ringtail cats (Bassariscus astutus) in the Sonoran Desert. M. S. Thesis, Arizona State University 61pp.

Clark, J. D., J. E. Dunn, and K. G. Smith. 1993. A multivariate model of female black bear habitat use for a GIS. J. Wildl. Manage. 57:519-525.

Clem, M. K. 1977. Food habits, weight changes, and habitat selection of fisher during winter. M.S. thesis., University of Guelph, Ontario.

Coulter, M. W. 1966. Ecology and management of fisher in Maine. Ph.D. dissertation, State Univ. of New York, Syracruse. 183pp.

de Vos, A. 1951. Overflow and dispersal of marten and fisher in Ontario. J. Wildl. Manage. 15:164-175.

Douglas, C. W., and M. A. Strickland. 1987. Fisher. Pages 510-527 *in* M. Novak, J.A. Baker, M.E. Obbard, and B. Malloch, editors. Wild Furbearer Management and Conservation in North America. Ministry of Nat. Res., Ontario.

Edwards, R. L. 1969. Archaeological use of the Universal Transverse Marketeer grid. American Antiquity 34:180-182.

Fowler, C. H., and R. T. Golightly. 1994. Fisher and marten survey techniques on the Tahoe National Forest. Final Report. Cal. Dept. Fish and Game, nongame bird and mammal Sec., Rep. 94-9. Sacramento,CA 64pp.

Franklin, J. F. 1993. Preserving biodiversity: species, ecosystems, or landscapes? Ecol. Appl. 3:202-205.

Fry, W. 1926. The California ringtailed cat. California Fish and Game, Sacramento, 12:77-78.

Gese, E. M., T. E. Stotts, and S. Grothe. 1996. Interactions between coyotes and red foxes in Yellowstone National Park, Wyoming. J. of Mammol. 77:377-382.

Golightly, R. T., and A. S. Seglund. In preparation. Fisher survey techniques on the Shasta-Trinity National forest. Progress report.

Grinell, J., J. S. Dixon, and J. M. Linsdale. 1937. Fur Bearing Mammals of California. Univ. of Calif. Press, Berkeley. 375pp.

Gutiérrez, R. J., A. B. Franklin, and W. S. LaHaye. 1995. Spotted owl (Strix occidentalis). A. Poole and F. Gill eds., The Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, D.C.

Hallberg, D. L., and G. R. Trapp. 1984. Gray fox temporal and spatial activity in a riparian/agricultural zone in California's Central Valley. Pages *in* R.E. Warner and K.M. Hendrix, editors. California Riparian Systems. Univ. of Calif. Press, Los Angeles, CA.

Haroldson, K. J., and E. K. Fritzell. 1984. Home ranges, activity, and habitat use by gray foxes in an oak-hickory forest. J. Wildl. Manage. 48:222-227.

Harris, S. 1981. The food of suburban foxes, with special reference to London. Mamm. Rev. 11:151-168.

Harrison, R. L. 1993. A survey of anthropogenic ecological factors potentially affecting gray foxes (Urocyon cinereoargenteus) in a rural residential area. Southwest. Natl. 38:352-356.

Harrison, D. J., J. A. Bissonette, and J. A. Sherburne. 1989. Spatial relationships between coyotes and red foxes in eastern Maine. J. Wildl. Manage. 53:181-185.

Heinemeyer, K. S. 1993. Temporal dynamics in the movements, habitat use, activity, and spacing of reintroduced fishers in northwestern Montana. M. S. thesis, Univ. of Montana, Missoula. 154pp.

Hellgren, E. C. 1993. Status, distribution, and summer food habits of black bears in Big Bend National Park. Southwest Natl. 38:77-80.

Hintze, J. L. 1995. NCSS 6.0 Users Guide. Number Cruncher Statistical Systems. Kaysville, Utah. 339-359pp.

Hintze, J. L. 1996. NCSS 6.1 Users Guide. Number Cruncher Statistical Systems. Kaysville, Utah. 339-359pp.

Holland, V. L., and D. J. Keil. 1990. California vegetation. California Polytechnic State University, San Luis Obispo, Calif. 318pp.

Hosomer, D. W., and S. Lemeshow. 1989. Applied logistic regression. John Wiley & Sons, New York. 245pp.

James, F. C., and H. H. Shugart, Jr. 1970. A quantitative method of habitat description. Audubon Field Notes 24:727-736.

Jones, J. L. 1991. Habitat use of fishers in northcentral Idaho. M.S. Thesis, Univ. of Idaho, Moscow. 147pp.

Jonkel, C. J. 1962. Black bear population studies. Montana Fish and Game Dept., Fed. Aid in Wildl. Restor. 18pp.

Johnson, S. A. 1984. Home range, movements, and habitat use of fishers in Wisconsin. M.S. Thesis, Univ. Wisconsin, Stevens Point. 78pp.

Kelly, G. M. 1977. Fisher (*Martes pennanti*) biology in the White Mountain National Forest and adjacent areas. Ph.D. thesis, Univ. of Massachusetts, Amherst. 178pp.

Kelleyhouse, D. G. 1975. Habitat utilization and ecology of the black bear in Northern California. M.S. Thesis, Calif. State Univ., Arcata. 58pp.

Kelleyhouse, D. G. 1977. Habitat utilization by black bears in Northern California. International Conf. Bear Res. and Manage. 222-227pp

Klenner, W. 1987. Seasonal movements and home range utilization patterns of the Black Bear, *Ursus americanus*, in western Manitoba. Can. Field Nat. 101:558-568 pp.

Larson, D. L., and C. E. Bock. 1986. Determining avian habitat preference by bird-centered vegetation sampling. Pages 37-44 *in* J. Verner, M. L. Morrison, and C. J. Ralph, editors. Wildlife 2000: Modelling habitat relationships of terrestrial vertebrates. Univ. Wisconsin Press, Madison.

Leonard, R. D. 1980. The winter activity and movements, winter diet, and breeding biology of fisher in southeastern Manitoba. M.S. thesis, Univ. of Manitoba, Winnipeg. 181pp.

Lewis, J. C., and Zielinski, W. J. 1996. Historical harvest and incidental capture of fishers in California. Northwest Sci. 70:291-297.

Manly, B., L. McDonald, and D. Thomas. 1993. Resource selection by animals. Chapman and Hall. New York 159pp.

Mayer, K. E., and W. F. Laudenslayer. 1988. A guide to wildlife habitats of California. Calif. Dept. Forestry and Fire Protection. Sacramento, CA. 166pp.

McGarigal, K., and B. J. Marks. 1994. Fragstats: Spatial pattern analysis program for quantifying landscape structure. Oregon State University, Corvallis. 59pp.

Noss, R. 1983. A regional approach to maintain biodiversity. BioScience 33:547-553.

Orloff, S. 1980. Ringtail distribution study. California Dept. of Fish and Game, Sacramento. 31pp.

Pereira, J. M., and R. M. Itami. 1991. GIS-based habitat modeling using logistic multiple regression: A study of the Mt. Graham red squirrel. Photo. Engin. and Remote Sensing. 57:1475-1486.

Piekielek, W., and T. S. Burton. 1975. A black bear population study in northern California. California Fish and Game 61:4-25.

Powell, R. A. 1982. The fisher: Life history, ecology, and behavior. Univ. Minnesota Press, Minneapolis, 127pp.

Raphael, M. G., and K. V. Rosenburg. 1986. Effects of forest fragmentation on vertebrates in doug-fir forests. Wildlife 2000: 263-272pp.

Reynolds, D. G. and J. J. Beecham. 1977. Home range activities and reproduction of black bears in west-central Idaho. International Conf. Bear Res. and Manage. 182-190.

Roy, K. S. 1991. Ecology of reintroduced fishers in the Cabinet Mountains of northwestern Montana. M. S. Thesis, Univ. of Montana, Missoula. 102pp.

Ruggerio, L. F. , K. B. Aubry, S. W. Buskirk, L. J. Lyon, and W. J. Zielinski. 1994. The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine. USDA Forest Service General Technical Report RM-254. 50-71pp.

Salwasser, H., C. K. Hamilton, W. B. Krohn, J. F. Lipscomb, and C. H. Thomas. 1983. Monitoring of wildlife and fish: Mandates and their implications. Transactions of the North American Wildl. and Nat. Resour. Conf. 45:245-251.

Schempf, P. F., and M. White. 1977. Status of six furbearer populations in the mountains of northern California. USDA Forest Service. Calif. Reg., unpubl. rep. 51pp.

Seglund, A. E. 1995. The use of rest sites by the Pacific Fisher. M.S. Thesis, Humboldt State University, Arcata. 66pp.

Stevens, J. 1992. Applied Multivariate Statistics for the social sciences. Lawrence Erlbaum Assoc. 542pp.

Trapp, G. R. 1978. Comparative behavioral ecology of the ringtail and gray fox in southwestern Utah. Carnivore 1:3-32.

Terbough, J. W. 1974. Preservation of natural diversity: The problem of extinction prone species. BioScience 24:715-722.

Toweill, D. E., and J. G. Teer. 1981. Home range and den habits of Texas ringtails (Bassariscus astutus flavus). Pages 1103-1120 *in* J. A. Chapman and D. Pursley, editors, Worldwide furbearer conference proceedings. Vol 2. Worldwide Furbearer Conference Inc., Lanham. 899pp.

Trani, M. K. 1976. Gray fox feeding ecology in relation to prey distribution and abundance. M.S. Thesis, Humboldt State University, Arcata. 102pp.

Trexler, J. C., and J. Travis. 1993. Nontraditional regression analysis. Ecology 6:1629-1637.

U. S. D. I. (United States Department of Interior). 1990. Proposed Trinity River Basin fish and wildlife management program. Frederiksen, Kamine, and Assoc. Portland. 305pp.

U. S. D. I. (United States Department of Interior). 1994. Standards and guidelines for management of habitat for late successional and old-growth forest related species within the range of the northern Spotted Owl: Final Supplemental Environmental Impact Statement. Appendix J2. Portland. 471pp.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. J. Wildl. Manage 47:893-901 pp.

Weins, J. A. 1989. Spatial scaling in ecology. Func. Ecol. 386-397.

Worton, B. J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70:164-168.

Zar, J. H. 1984. Biostatistical Analysis. Prentice-Hall Inc., Englewood Cliffs, New Jersey. 385 pp.

Appendix A. Agreement between satellite imagery and ground derived vegetation types (from 200 plots at the study area), and between LSAT and ground derived canopy closure classes provided by U.S.D.A. Forest Service, Pacific Southwest Research Station, Fresno, CA. Vegetation types and canopy closure classes for the ground plots were determined using a densiometer.

Vegetation Classes	User's Accuracy (%)
4 Vegetation Classes	
Conifer	68
Mixed	37
Hardwood	50
Shrub/Chapparal	25
* Overall Classification Accuracy (based on estimates with a densiometer) = 56%	
3 Vegetation Classes	
Conifer	68
Hardwood	59
Shrub/Chaparral	25
*Overall Classification Accuracy (based on estimates with a densiometer) = 63%	
4 Canopy Closure Classes	
Dense (76-100%)	89
Moderate (50-75%)	33
Open (25-49%)	50
Sparse (0-24%)	14
* Overall Classification Accuracy (based on estimates with a densiometer) = 67%	
* Road Classification Accuracy (Table 1) = 90%	

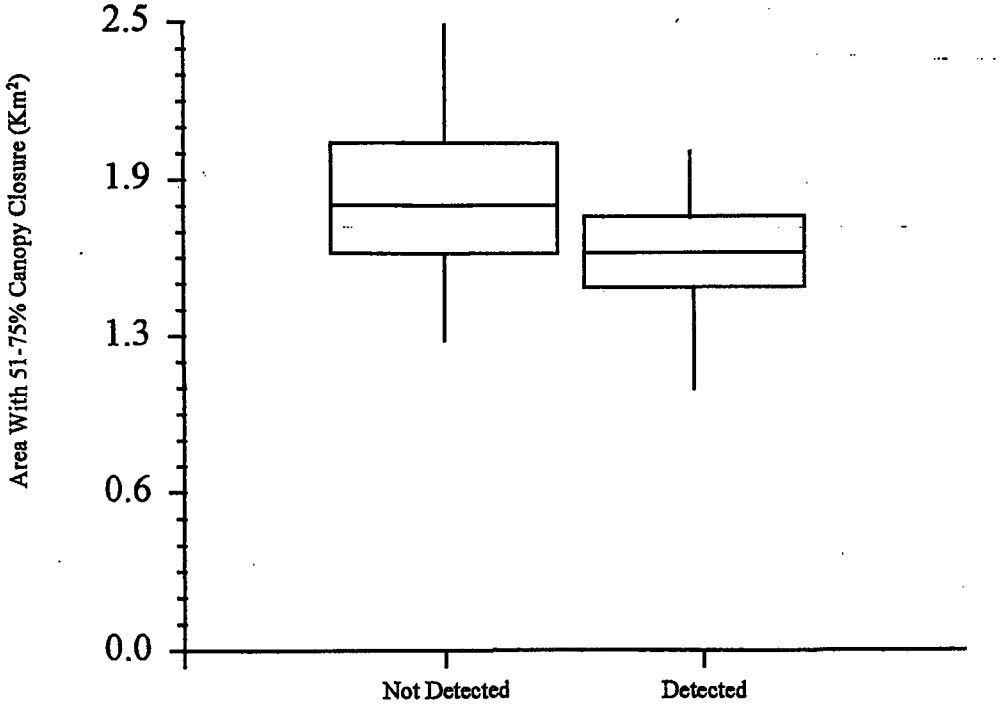
Appendix B. Measurements recorded for fisher trapped and radio collared on the Shasta-Trinity National Forest from May, 1993 to December, 1994. Measurements prior to August, 1993 were recorded by Seglund (1995).

Fisher ID	Sex	Date of Capture	Weight (kg)	Total Length (cm)	Body Circ. (cm)	Neck Circ. (cm)	Tail Length (cm)
#01	M	6/22/93	3.55	100.2	32.4	20.3	37.0
#01	M	7/26/93	4.80	104.0	32.0	21.0	37.0
#02	F	6/30/92	2.05	92.0	23.0	17.5	34.0
#03	F	7/02/93	2.05	93.8	25.0	16.3	36.8
#04	F	7/02/92	2.15	92.0	25.5	17.0	39.8
#04	F	6/16/93	2.25	92.0	29.0	17.0	39.8
#05	F	8/25/92	2.15	85.0	25.0	15.5	33.0
#06	F	12/04/92	2.11	93.0	25.0	17.5	35.0
#07	F	12/17/92	1.95	89.0	22.0	16.0	36.0
#08	M	6/12/93	2.30	92.5	26.0	18.0	37.0
#09	M	7/13/93	4.20	97.0	33.0	23.3	34.0
#10	F	7/19/93	2.30	94.0	26.0	16.5	37.0
#11	M	12/06/93	3.80	101.0	34.0	25.5	40.0
#12	M	01/09/94	4.50	103.0	31.0	12.5	39.0
#13	M	03/07/94	4.20	---	---	---	---
#14	F	06/08/94	2.38	92.0	20.0	18.5	31.0
#15	F	10/30/94	2.00	82.0	19.5	13.8	34.0
#16	M	11/14/94	4.0	101.0	28.0	---	34.0
#17	M	04/12/95	---	101.5	---	---	34.5

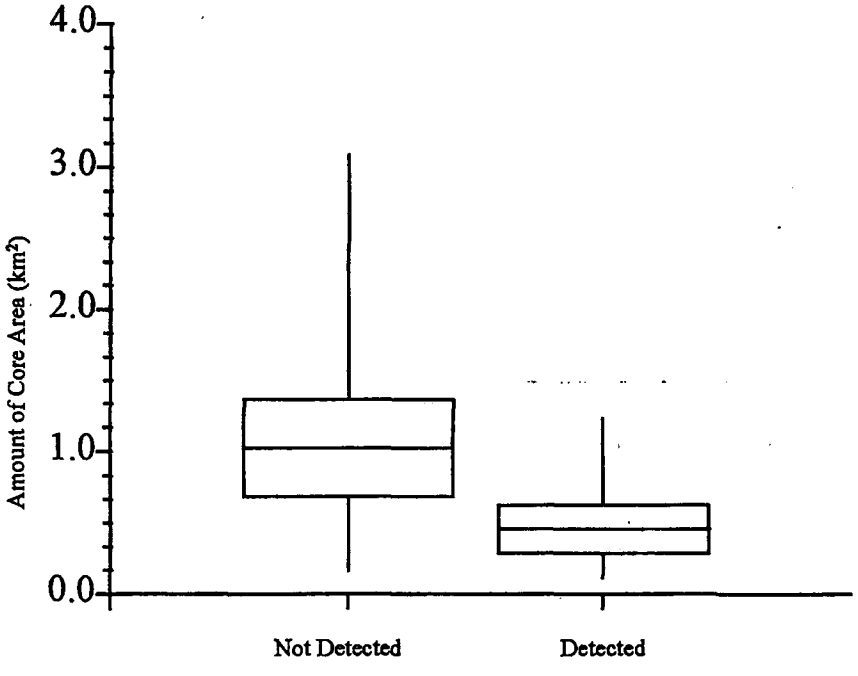
Appendix C. Estimated home range size for 11 fisher monitored on the Shasta-Trinity National Forest from May, 1992 through December, 1994.

Animal	Sex	Dates Monitored	Number of Locations	MCP (ha)	95% Adapative Kernel (ha)
#01	M	6/93 - 11/93	21	666.41	1144.17
#02	F	9/92 - 6/93	17	879.45	1920.54
#03	M	9/92 - 9/94	60	5236.52	4649.47
#04	M	12/93 - 12/94	22	1152.35	1909.06
#05	F	6/94 - 10/94	8	232.94	313.98
#06	F	7/92 - 9/92	8	210.45	389.62
#07	F	9/92 - 3-93	13	1792.10	4458.14
#08	F	9/92 - 1/93	8	1257.97	3033.67
#09	M	7/93 - 6/94	39	7664.03	13863.55
#10	F	2/93 - 6/94	30	4366.97	8772.46
#11	F	7/93 - 12/93	7	278.65	615.77

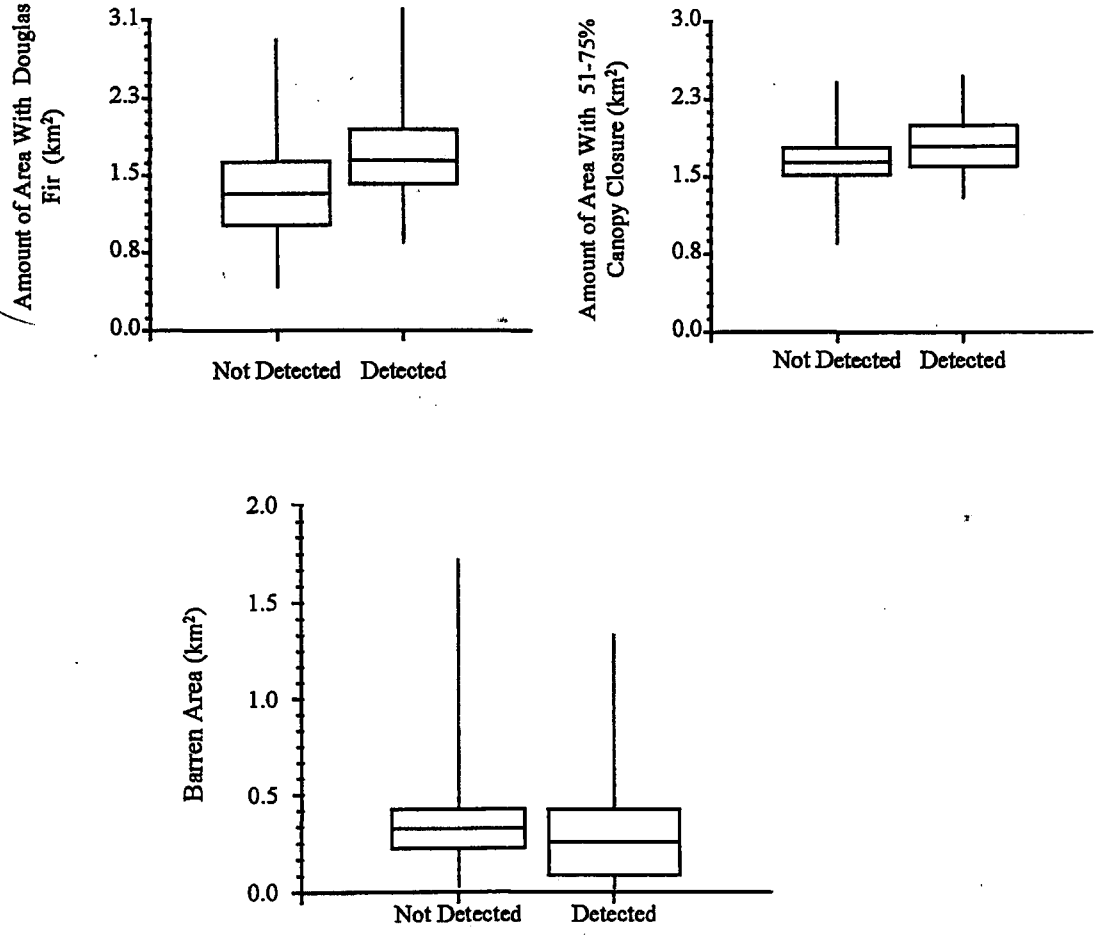
Appendix D. The amount of area with 51-75% canopy closure (km^2) in buffers where black bear were detected versus where they were not detected during the summer of 1994 and 1995 on the Shasta-Trinity National Forest. Vertical lines extend to the minimum and maximum values. Rectangular box represents ± 2 SE and the center horizontal line represents the mean.



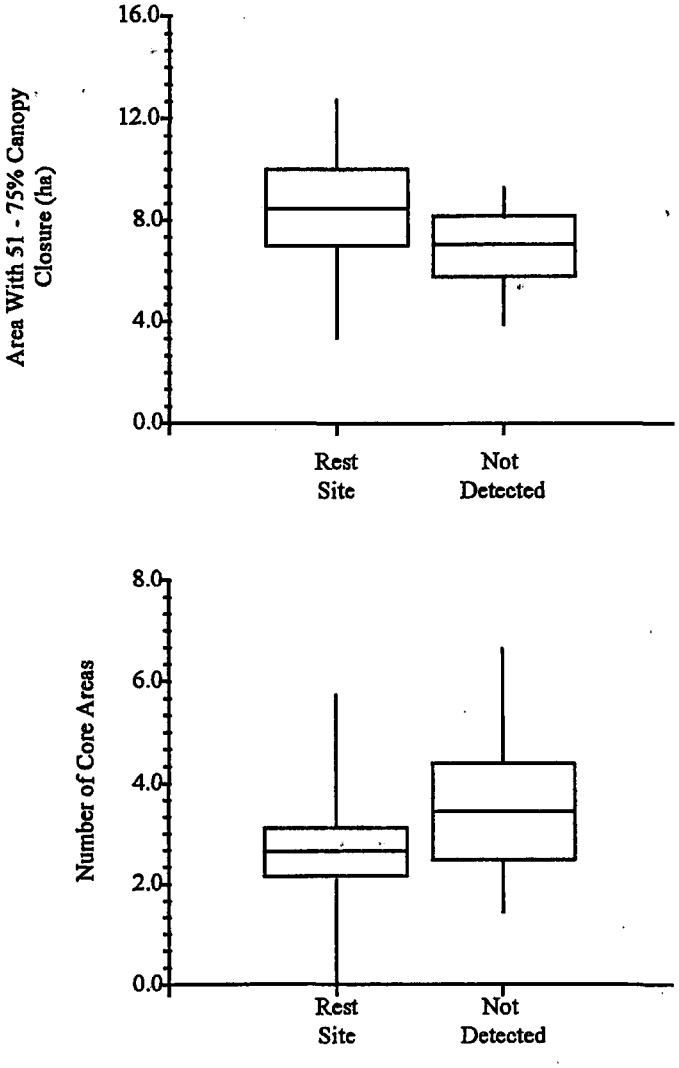
Appendix E. Amount of core area (km^2) in buffers where ringtail were detected and where they were not detected. Surveys were conducted on the Shasta -Trinity National Forest from May 1994 to August 1995. Vertical lines extends to the minimum and maximum values. Rectangular box represents ± 2 SE and the center horizontal line represents the mean.



Appendix F. The amount of area with 51-75% canopy cover, Douglas-fir (WHR Type), and barren area in buffers where fisher were detected and where they were not detected. Surveys were conducted on the Shasta-Trinity National Forest during the fall of 1994 and summers of 1994 and 1995. Vertical sines extended to the minimum and maximum values. Rectangular box represents ± 2 SE and the center horizontal line represents the mean.



Appendix G. The amount of area with Douglas-fir (ha) and number of core areas (ha) in circular buffers around fisher rest sites and stations without fisher detections (within fisher home ranges). All locations were on the east side of Clair Engle Lake. Data were collected from May through October in 1994 and 1995 on the Shasta-Trinity National Forest in Shasta and Trinity Counties. Vertical lines extend to the minimum and maximum values. Rectangular box represents ± 2 SE and the center horizontal line represents the mean.



Appendix H. The amount of area Douglas-fir (ha), number of core areas, amount of barren area, and area of mixed conifer in circular buffers around fisher rest sites and stations without fisher detections (within fisher home ranges). All locations were on the west side of Clair Engle Lake. Data were collected from May through October in 1994 and 1995 on the Shasta-Trinity National Forest in Shasta and Trinity Counties. Vertical lines extend to the minimum and maximum values. Rectangular box represents ± 2 SE and the center horizontal line represents the mean.